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March 26, 2010

Mr. Ross del Rosario
Ms. TaNaisha Lee
Ms. Sheila Sullivan, M.P.H.
Mr. Pablo Valentín

958969

Remedial Project Managers
USEPA, Region 5
77 W. Jackson Boulevard
Chicago, Illinois 60604-3590

RE: **Multi-Site Feasibility Study Support Document – Revision 1**
Integrys Business Support, LLC Former Manufactured Gas Plant Sites

North Shore Gas Company CERCLA Docket No. V-W-07-C-877
Peoples Gas and Light CERCLA Docket No. V-W-08-C-917
Wisconsin Public Service Corporation CERCLA Docket No. V-W-06-C-847 (WI Multi-Site)
Wisconsin Public Service Corporation CERCLA Docket No. V-W-07-C-862 (Campmarina)

Dear Mr. del Rosario, Ms. Lee, Ms. Sullivan, and Mr. Valentín:

Please find enclosed one hard copy and one electronic copy (for each) of the Multi-Site Feasibility Study (FS) Support Document – Revision 1, dated March 26, 2010 for your review. This document incorporates USEPA's March 17, 2010 comment on the Multi-Site FS Support Document – Revision 0 (July 16, 2009) in Sections 2.3, 2.4, and 2.6.

The Multi-Site FS Support document addresses former manufactured gas plants (MGPs) operated by Wisconsin Public Service Corporation (WPSC), The Peoples Gas Light and Coke Company (Peoples Gas), and North Shore Gas Company (North Shore Gas). Each of the sites are managed by Integrys Business Support, LLC (IBS) in accordance with the Statements of Work (SOW) attached to the Settlement Agreements and Administrative Orders on Consent (Settlement Agreements) between the United States Environmental Protection Agency (USEPA) and (WPSC) effective May 5, 2006 and January 26, 2007 (Wisconsin Multi-Site and Sheboygan-Campmarina Settlement Agreements, respectively); Peoples Gas effective October 30, 2008; and the North Shore Gas effective July 23, 2007.

Please do not hesitate to contact me at 312.240.4569 if you have any questions regarding this document.

Sincerely,

Naren Prasad

Naren Prasad, P.E., MPH, LEED AP
Project Coordinator / Senior Environmental Engineer

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MULTI-SITE FEASIBILITY STUDY SUPPORT DOCUMENT
FORMER MANUFACTURED GAS PLANT SITES

Prepared For:
Wisconsin Public Service Corporation, Peoples Gas Light and Coke Company, North Shore Gas Company

Managed By:

Integrys Business Support, LLC
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Prepared For Use By:

The Consultant/Contractor

Revision 1
March 26, 2010

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TABLES

ACRONYMS

ARAR	Applicable or Relevant and Appropriate Requirements
CERCLA (ñSuperfund")	Comprehensive Environmental Response, Compensation, and Liability Act
cm/sec	Centimeters per Second
COPCs	Contaminants of Potential Concern
CFR	Code of Federal Regulations
CROW	Contained Recovery of Oily Waste
CSM	Conceptual Site Model
DNAPL	Dense Non-aqueous Phase Liquid
ERH	Electrical Resistance Heating
FS	Feasibility Study
HDPE	High Density Polyethylene
HVAC	Heating, Ventilation and Air Conditioning
ICIAP	Institutional Control Implementation Action Plan
IBS	Integrys Business Support, LLC
ISEE	In-situ Steam-Enhanced Extraction
ISCO	In-situ Chemical Oxidation
ISS	In-situ Solidification/Stabilization
MGP	Manufactured Gas Plant
MNA	Monitored Natural Attenuation
LNAPL	Light Non-aqueous Phase Liquid
MNR	Monitored Natural Recovery
NAPL	Non-aqueous Phase Liquid
NCP	National Contingency Plan
North Shore Gas	North Shore Gas Company
O&M	Operation and Maintenance
PAHs	Polynuclear Aromatic Hydrocarbons
Peoples Gas	Peoples Gas Light and Coke Company
PPT	Pressure Pulse Technology
PRB	Permeable Reactive Barriers
PRG	Preliminary Remediation Goal
PVC	Polyvinyl chloride
PVOC	Petroleum Volatile Organic Compounds
ROD	Record of Decision
RAO	Remedial Action Objective
RI	Remedial Investigation

ACRONYMS CONTINUED

RAF	Risk Assessment Framework
SERP	Steam-Enhanced Recovery Process
Settlement Agreement	Settlement Agreement and Administrative Order on Consent
SISCO	Surfactant ï Enhanced In-situ Chemical Oxidation
SIVE	Steam Injection and Vacuum Extraction
SOW	Statement of Work
SVE	Soil Vapor Extraction
TBC	To Be Considered
TCH	Thermal Conductive Heating
TSD	Treatment/Storage/Disposal
USEPA	United States Environmental Protection Agency
WPSC	Wisconsin Public Service Corporation

1 INTRODUCTION

1.1 Purpose

This Multi-Site Feasibility Study (FS) Support Document was prepared in accordance with the Statements of Work (SOW) attached to the Settlement Agreements and Administrative Orders on Consent (Settlement Agreements) between the United States Environmental Protection Agency (USEPA) and Wisconsin Public Service Corporation (WPSC) effective May 5, 2006 and January 26, 2007 (Wisconsin Multi-Site and Sheboygan-Campmarina Settlement Agreements, respectively); The Peoples Gas Light and Coke Company (Peoples Gas) effective October 30, 2008; and the North Shore Gas Company (North Shore Gas) effective July 23, 2007. The Multi-Site FS Support document addresses former manufactured gas plants (MGPs) operated by WPSC, Peoples Gas, and North Shore Gas, (collectively, the Company). Integrys Business Support, LLC (IBS) is managing the work in the Settlement Agreements on behalf of the Company.

This Multi-Site FS Support Document provides a basis for Site-Specific FS evaluations at each of the sites included in the Settlement Agreements. General response actions and preliminary remedial technologies presented herein will be used as a framework to develop and evaluate site-specific remedial alternatives. The Site-Specific FS will consider the constraints and conditions of each site within the framework of the Multi-Site FS Support Document to develop appropriate remedial alternatives. This document also presents a list of Applicable or Relevant and Appropriate Requirements (ARARs) and permitting equivalency requirements at the federal and state levels. These ARARs represent ARARs which may be applicable on a site-specific basis. Depending on local conditions, a particular ARAR listed in this Multi-Site FS Support Document may or may not be applicable. Finally, this document discusses how the Multi-Site FS Support Document will be used on a site-specific basis.

This Multi-Site FS Support Document was prepared to incorporate elements of ñGuidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLAò, USEPA, Office of Emergency and Remedial Response, October 1988, OSWER Directive No. 9355.3-01, (the RI/FS Guidance Document

USEPA 1988), Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, December 2005, and other guidance as attached to the SOW.

1.2 Background

The MGP sites listed in the Settlement Agreements have some common characteristics that should be understood when evaluating remedial technologies. These common characteristics are further discussed in the Generalized Conceptual Site Model (CSM, August 2007). The majority of the MGPs operated using the coal carbonization and/or carbureted water gas method. As a result, similar waste and by-products were produced. Based on previous investigations at the Company MGP sites and as discussed in the Multi-Site Risk Assessment Framework (RAF (Exponent, 2007)), the common constituents of potential concern (COPCs) include polycyclic aromatic hydrocarbons (PAHs) and petroleum volatile organic compounds (PVOCs). The most common media of concern include groundwater, soil, and sediments. In addition, dense non-aqueous phase liquid (DNAPL) is considered a separate media of concern. Finally, vapor intrusion from contaminated groundwater and/or soil may also present a concern.

Development of remedial technologies appropriate for the MGP sites presented in this FS Support Document is based on previous MGP remediation experience and knowledge of each site, generically presented below:

- MGPs were dismantled and in most cases, the sites were re-developed;
- Current and reasonably anticipated future land uses may include residential, commercial, industrial or recreational (park) settings in urban areas. Buildings (residential, commercial or industrial) may be located within or adjacent to the former MGP property;
- Many of the former MGPs are adjacent to water bodies (rivers or canals) which are generally affected by non-MGP sources;
- Groundwater is typically shallow and not used as a drinking water source;
- Geology varies from fill, sand to clay units overlying bedrock; and
- Upland remedial actions may have been performed, to varying degrees, prior to entering the Settlement Agreements.

These conditions will be considered on a site-specific basis to select appropriate remedial technologies for assembled alternatives in the Site-Specific FS.

1.3 Objectives

This Multi-Site FS Support Document addresses the following SOW elements:

- Section 2: Preliminary Remedial Technology Screening;
- Section 3: Preliminary List of Possible ARARs; and
- Section 4: Preliminary Permitting/Equivalency Requirements.

In addition, Section 5 of this document provides an overview of how the Multi-Site FS Support Document will be used to prepare the Site-Specific FS. Site-Specific FS Reports will evaluate remedial alternatives to address exposure pathways associated with potential risk, remedial action objectives (RAOs), and preliminary remediation goals (PRGs).

References are provided in Section 6.

2 PRELIMINARY REMEDIAL TECHNOLOGY SCREENING

This section identifies general response actions and a preliminary list of remedial technologies to address the following media:

- Contaminated groundwater;
- Contaminated soil;
- Contaminated sediments;
- DNAPL; and
- Vapor Intrusion.

General response actions describe those actions that will satisfy the RAOs. Development of the general response actions and remedial technologies is based on knowledge of each site (generically represented) and discussions with USEPA on May 18, 2009. Remedial technologies and process options presented in this FS Support Document are all relevant to MGP sites, addressing the typical COPCs that are also listed in the Multi-Site RAF (Exponent, 2007). Additional remedial technologies may be identified in each Site-Specific FS, depending on site-specific conditions and site-specific COPCs.

General response actions appropriate for the MGP sites are summarized on Table 2. Remedial technologies and related process options that potentially would achieve RAOs for each media of concern are discussed on Table 3A through 3E (groundwater, soil, sediment, DNAPL, and soil vapor, respectively) with respect to the following criteria:

- Effectiveness: This criterion evaluates the ability of a technology to achieve the RAOs and to provide long-term protection of human health and the environment. Potential short-term impacts to human health and the environment, and the reliability of the technology are also discussed;
- Implementability: This criterion addresses the technical and administrative feasibility of implementing the technology as well as the availability of contractors and materials, potential

site constraints (on- and off-site) to be considered, the difficulties monitoring the effectiveness of the process option, and agency coordination or permits; and

- Cost: This criterion utilizes engineering judgment to develop general, relative estimated costs of each technology. The cost estimates are qualitative (low, moderate and high) for typical site conditions.

These criteria will be used on a site-specific basis in forthcoming Site-Specific FS Reports to identify technologies to be retained or eliminated for further consideration in developing remedial alternatives.

In addition to the three criteria listed above, a green remediation based qualitative assessment of the response actions may be conducted, taking into account site-specific factors. If performed, the objective of the assessment will be to consider broader environmental effects of remedy implementation to maximize net environmental benefit. The assessment would be for informational purposes and would only be performed on those remedial alternatives that are otherwise considered to be protective of human health and the environment. In performing the green remediation assessment, remedial alternatives will be compared by qualitatively evaluating the ñcarbon footprintò, beneficial re-use, or other ñgreenò qualities associated with each remedy. Using this approach will inform USEPA and the public so as to allow for a balance to be determined between what is necessary on a local basis to be protective of local risks and the global risk associated the proposed work.

The following sections provide a brief overview of the remedial technology process.

2.1 No-Further Action

Consistent with the National Contingency Plan (NCP), contained in 40 Code of Federal Regulations (CFR) 300, a No-Further Action technology is considered for each media. No-Further Action does not include any remedial action component or monitoring to minimize potential exposures related to contaminated media at a site. The No-Further Action technology or alternative is used as a baseline for comparison of other technologies or assembled remedial alternatives.

2.2 Institutional Controls

Institutional controls are non-engineered instruments, such as administrative and legal controls, that may be included as part of the remedial action for any media to ensure the long-term protectiveness of the remedial action. The institutional controls affect human activities to reduce exposure to affected media. Institutional controls may be used to maintain the integrity of the remedial alternative, including zoning restrictions, groundwater use restrictions or protection of capped areas (soil and sediment), where affected media may remain after completion of the remedial action.

Short-term and long-term institutional controls may be implemented to minimize potential human health and ecological exposures. Under some site conditions, use of institutional controls will be protective of human health and the environment in areas of the site with media exceeding PRGs. This is particularly true at sites where remediation efforts have already occurred. Media-specific examples of institutional controls are presented in Tables 3A through 3E.

An Institutional Control Implementation Action Plan (ICIAP) would be developed to detail restrictions and document procedures for effectively implementing the institutional control. Institutional controls are assessed in Five-Year Reviews.

2.3 Groundwater

Remedial technologies that address groundwater are presented below. Groundwater contamination can be the result of both non-aqueous phase liquid (NAPL) and dissolved-phase contaminants. At former MGP sites, light non-aqueous phase liquid (LNAPL), DNAPL (or tar), and dissolved phase contamination may be present, although DNAPL may be more prevalent than LNAPL. Also, groundwater may be contaminated by other sources that are, or were located upgradient from the site, or on-site. For the purposes of this FS Support Document, the following technologies focus on dissolved-phase COPCs in groundwater, contaminated as a result of former MGP operations, and DNAPL is addressed separately in Section 2.6.

It should also be understood that implementing a remedial technology that addresses dissolved phase contamination by itself may not be effective if DNAPL, tar or contaminated soil are present. It may be necessary to replace standard schedule 40 polyvinyl chloride (PVC) constructed groundwater monitoring wells with other chemically resistant groundwater monitoring well materials (e.g. stainless steel) if the PVC wells become damaged as a result of significant volumes of NAPL in the subsurface. Replacement wells will be installed on a site-specific basis as part of long-term monitoring plans in areas of NAPL plumes, as necessary.

2.3.1 Containment

The following remedial technologies provide containment of groundwater:

- Physical Barriers; and
- Gradient Control Pumping.

Physical or subsurface barriers are often composed of sheet piling, high density polyethylene (HDPE) or soil, bentonite and concrete slurry walls. The barriers are used to contain and/or divert contaminated groundwater away from sensitive areas such as the zone of capture for drinking water wells. The barriers can also provide a barrier for the groundwater treatment system. The vertical barriers are keyed into an underlying impervious geologic unit to prevent lateral migration.

Physical barriers are effective at containing, diverting and/or isolating groundwater. Barriers are often combined with other technologies in order to effectively capture groundwater prior to treating or removing contaminated groundwater. The physical barrier's wall composition may degrade, deteriorate, or be damaged by nearby activity. As a result, physical barriers may require continued monitoring inside and outside the wall for potential leakage from the containment area. This technology has been extensively used in the past which allows for a wide range of system choices and capabilities. On a scale of low, moderate and high, the relative cost of this technology compared to other groundwater remediation alternatives is moderate.

Gradient control pumping is also a form of containment. A pumping system can be designed to capture the contaminant plume, thereby preventing further downgradient migration. This system is generally used with treatment of affected groundwater and discharge of treated effluent. Gradient control pumping may become costly to operate and monitor, and used by itself, does not reduce groundwater concentrations appreciably. The relative cost of this type of containment is moderate.

2.3.2 In-Situ Treatment

In-situ treatment of groundwater is a viable option when the following conditions are present on a site:

- Buildings, structures or other obstructions are present that prohibit excavation and direct access to the affected groundwater;
- Groundwater is deep so direct access is complicated and costly;
- An immediate threat to a public water supply is not present, or there are no nearby receptors; and
- Other site-specific conditions.

The following in-situ remedial technologies/process options address groundwater:

- Enhanced Bioremediation;
- Air Sparging;
- Chemical Oxidation; and
- Permeable Reactive Barriers (PRBs).

Enhanced Bioremediation - Enhanced bioremediation describes the process that occurs when either naturally occurring or supplemented micro-organisms degrade the organic contaminants in the groundwater. The process utilizes a system where nutrients are directed to the area of concern by means of wells in order to enhance naturally occurring microbes and increase biodegradation. This process is often used in conjunction with Soil Vapor Extraction (SVE) (refer to Section 2.4.2) to address vadose-zone contamination. Injection of gases can induce the movement of groundwater flow, so it may be necessary to also use gradient control pumping (and possibly a treatment system) to assist in the control of the groundwater. Commonly added nutrients are hydrogen peroxide and nitrate.

Enhanced Bioremediation is effective for PAHs, and moderately effective for PVOCs. It is less effective if significant sources of contamination in the form of free product are still present. Hydrogen peroxide injection can greatly increase the supply of oxygen for microbes to use in biodegradation, while nitrate can be used to decrease the supply of oxygen for microbes to use in anaerobic biodegradation. The gaseous injection system may also include a recovery system. Cold weather climates may slow the remediation process and the use of heat blankets to control soil temperature may need to be evaluated. Bio-fouling (clustering of microbes near nutrients at injection wells) of the wells can occur and requires maintenance and potentially a rotation schedule of injection wells.

This technology also requires continued monitoring inside and outside the injection zones. There is a limited ability of recovery in stratified soils with low permeability layers such as clay or fractured rock. Safety precautions and systems need to be in place for chemical storage and injection. Anaerobic degradation of chemicals can lead to potentially more dangerous intermediate stages. The relative cost of this technology is moderate to high.

Air Sparging - The air sparging process uses horizontal or vertical wells to inject air directly into the groundwater and is used with a SVE system to extract PVOCs being volatilized by the presence of the injected air.

Air sparging is effective for contaminants that volatilize in the presence of air, such as some PAHs and PVOCs. However it is not an effective technology if significant sources of contamination in the form of free product are still present. Air sparging may disrupt groundwater flow patterns and biological activities in the saturated and vadose soil zones by the large volume of air being pumped into the groundwater. The air injection system must also include a recovery system to recover the volatilized contaminants. The introduction of large amounts of air in horizontal wells may induce plume migration. This technology also requires continued monitoring inside and outside the injection zones. Contaminant recovery in stratified soils with low permeability layers such as clay or fractured rock may be limited. The SVE system or other recovery systems may generate waste in the form of spent filter media or groundwater. The relative cost of this technology compared to the other groundwater remedial alternatives is moderate to high.

Chemical Oxidation - Chemical oxidation converts contaminants to reduced levels of compounds that are more stable, less mobile, and/or inert. Chemicals oxidants most often used for this treatment method include peroxide, ozone, and permanganate. The chemical oxidants are injected using a system of injection wells.

The rate and extent of degradation of contaminants are dictated by the properties of the chemical itself and its ability to be oxidized as well as the soil and groundwater conditions; most notably, pH, temperature, the concentration of oxidant, and the concentration of other oxidant-consuming substances such as natural organic matter. Given the relatively indiscriminate and rapid rate of reaction of the oxidants with reduced substances, the method of delivery and distribution throughout a subsurface is important. Oxidant delivery systems often employ vertical or horizontal injection wells and sparge points with forced advection to rapidly move the oxidant into the subsurface.

Permanganate is relatively more stable and relatively more persistent in the subsurface; as a result, it can migrate by diffusive processes. Consideration also must be given to the effects of oxidation on the system. Oxidation reactions can decrease the pH if the system is not buffered effectively. Other potential oxidation-induced effects include: reduced permeability; mobilization of redox-sensitive and exchangeable sorbed metals; possible formation of toxic byproducts; evolution of heat and gas; and biological perturbation. Engineering of in-situ chemical oxidation must be done with due attention paid to reaction chemistry and transport processes. It is also critical that close attention be paid to worker training and safe handling of process chemicals as well as proper management of remediation wastes. The design and implementation process should rely on an integrated effort involving screening level characterization tests and reaction transport modeling, combined with treatability studies at the lab and field scale. The relative cost of this technology is moderate to high.

Permeable Reactive Barriers - PRBs are a passive technology using a permeable barrier downgradient from the flow of a plume and physical barriers (such as a slurry wall or sheet pile wall) to direct the flow of the groundwater. The walls are installed across the flow path of the plume. A media, often iron or peat is located in the barrier and reacts with the contaminants causing them to either precipitate, stabilize, or adhere to the media.

PRBs are effective at managing hydraulic flow and treating the groundwater. This passive technology requires reduced operational costs since there are no mechanical parts or operations to the system. PRBs are also effective at allowing groundwater flow to direct the transporting and recovering of DNAPL.

There are low short-term exposure risks (odors and construction worker and community exposures) with this technology. This system does require maintenance and replacement of PRB media; resulting in disposal of the contaminated media. The treatment wall can lose its effectiveness over time as media selected may lose its reactive capability and may need to be removed and replaced. The overall effectiveness and timeframe of PRB recovery is unknown. In addition, PRBs are difficult to construct in highly variable groundwater flow conditions or where cross groundwater currents, seasonal or long term groundwater flow direction can change. Continued monitoring inside and outside of the barriers is required to ensure the continued groundwater flow through the PRB. The relative cost of this technology is moderate to high.

2.3.3 Ex-Situ Treatment

Ex-situ groundwater treatment is a viable option to consider when immediate collection or containment is necessary to protect nearby receptors, or other media such as DNAPL is present that is being removed (see Section 2.6). The following ex-situ remedial technologies/process options address groundwater:

- Groundwater Pump and Treat; and
- Excavation/Trenching.

Groundwater Pump and Treat - Groundwater Pump and Treat uses a variety of methods by which groundwater is pumped from extraction wells, sumps, or trenches and discharged or is treated ex-situ. Pumping may also be used for containment in the form of hydraulic control (see Section 2.3.1) limiting flow and contaminant migration.

Groundwater pump and treat is effective for a wide range of contaminants and moderately effective in the recovery of free product. This technology may be used in conjunction with other technologies that improve recovery. Residual saturation of the contaminant in the soil pores cannot be removed by groundwater pumping. Contaminants tend to be sorbed in the soil matrix and may require alternative remedial technologies to improve recovery of the contaminants. The overall system effectiveness and timeframe of pump and treat recovery is difficult to accurately forecast. This technology option was extensively used in the past, which allows for a wide range of system choices and capabilities. Groundwater pumping is not applicable for contaminants with high residual saturation, contaminants with high sorption capabilities and homogeneous aquifers with hydraulic conductivity less than 10^{-5} centimeters per second (cm/sec). This system requires maintenance/replacement of treatment media, activated carbon or other media. Proper disposal of the media waste generated or collected groundwater sent for disposal is necessary. The relative cost of this technology is moderate to high.

Excavation/Trenching - Excavation/Trenching involves removal of soil or free product above and below the water table elevation either to remove the mass of contaminants or to collect groundwater. The excavated soil is staged, treated on-site, or directly loaded into trucks and properly disposed. The water that accumulates may then be pumped and treated or pumped and properly disposed. The on-site treated soil or virgin soil and/or stone are often used to backfill the excavation pits or trenches.

Excavation/trenching is effective for a wide range of contaminants. This technology requires engineering, earth retention system design and installation, erosion and access controls during construction for managing fugitive emissions, soil, and public access. This technology enables the removal of affected source material and/or affected soil to provide access to groundwater. However, subsurface structures or above ground structures may make this technology less effective. This technology is a highly effective and allows for a predictable timetable. There are often limitations based on the availability of required space for staging and handling of soil material and water treatment system, if needed. Air quality controls need to be addressed for emissions and dust. The depth to groundwater should also be considered, since deeper excavations are more difficult and costly to implement. Buildings or other structures that are located above impacts that cannot be removed can also limit the use of this technology. The relative cost of this technology is high.

2.3.4 Monitored Natural Attenuation

Monitored natural attenuation (MNA) by itself, may be suitable for addressing residual contamination or limited contamination in groundwater. Otherwise, it may be suitable to address residuals following a remedial action that addresses free product, tar or significant sources of contamination. MNA by biological and chemical degradation is a process to verify that loss of contaminants is naturally occurring and that contaminant degradation and natural processes will reduce contaminant concentrations to acceptable levels. Biological and chemical degradation can be demonstrated through a groundwater sampling network, contaminant trend analysis, mass balance calculations and modeling.

MNA relies on natural hydraulic flow, biodegradation, sorption to soil, and low bioavailability to microorganisms. Effectiveness and timeframe of natural attenuation varies by site and may require an extended time frame. MNA is dependent on physical and biological characteristics of the ecosystem. This technology does not further damage existing habitat or biological community. MNA biological and chemical degradation is easily implemented and monitoring is conducted with well-established methods. Limited construction or infrastructure required and little disruption to local residents occurs. MNA can be combined with other remedial options. There are no by-products or wastes generated by the implementation of this technology. The relative cost of this technology is low to moderate.

2.4 Soil

As used in this section, soil is described as contaminated material that lies above the water table, within the smear zone, or below the water table. It addresses tar saturated soil located either in the vadose zone or below the water table. It is different than DNAPL, since DNAPL, as used in this FS Support Document, is defined below as the liquid that does not sorb to the soil, and is a separate phase. Many of the technologies are more appropriate for situations where the subsurface soil is contaminated, but the technology can be applied to the surface as well. If only surface soil was contaminated, many of these technologies would not be considered.

As discussed in Section 2.3, it may be necessary to replace standard schedule 40 polyvinyl chloride (PVC) constructed groundwater monitoring wells with other chemically resistant groundwater monitoring well materials (e.g. stainless steel) if the PVC wells become damaged as a result of significant volumes of NAPL in the subsurface. Replacement wells will be installed on a site-specific basis as part of long-term monitoring plans in areas of NAPL plumes, as necessary.

2.4.1 Capping/Containment

The following remedial technology/process options provide soil containment:

- Soil caps;
- Asphalt or concrete caps; and
- Multi-layer or geosynthetic caps.

Capping/engineered barriers include using a selected thickness of soil or aggregate to provide a barrier, asphalt or concrete to provide an impervious barrier, and geosynthetic covers (or geosynthetics combined with earthen materials) to provide caps that are impervious and include drainage layers and redundancy. Caps are used for creating a physical barrier separation between the affected soil and the surface.

Capping/engineered barriers do not treat the soil or groundwater, but enables the isolation of affected soil. Impervious barriers also minimize continued migration of contaminants from the soil to the underlying groundwater due to incidental precipitation. Multi-layered caps may include redundancy by using soil and a geosynthetic liner, or another combination of materials to provide increased protection. Capping material composition may degrade, deteriorate, or be damaged. This technology also requires continued monitoring and potentially maintenance in the capped areas for cap or barrier degradation. The relative cost of this technology is low to moderate, depending on the aerial extent.

2.4.2 In-Situ Treatment

The following in-situ technologies or technology types are evaluated:

- Solidification/Stabilization (ISS);
- Soil Vapor Extraction (SVE);
- Chemical and Surfactant ï Enhanced Oxidation (ISCO and SISCO); and
- Thermal Treatments, including Hot Water and Steam Flushing/ Stripping and Thermal Conductive Heating (TCH).

Solidification/Stabilization - Solidification and stabilization are terms used to describe two technologies that are closely related. Both technologies use chemical or physical processes to reduce potential adverse effects to the environment from contaminated soil, sediment, and sludge. Each of these technologies is defined below:

- Solidification: This is primarily a physical process whereby the contaminated media (soil, sediment, or sludge) is converted into a solid, monolithic material that is more resistant to physical degradation and less susceptible to leaching than the untreated material. Contaminants are encapsulated and immobilized in the solidified matrix to reduce long-term mobility and toxicity.

- Stabilization: This is primarily a chemical process whereby contaminants within the media are converted into less soluble, mobile, or toxic forms. This process is more strongly related to constituents such as metals or other constituents that have the ability to chemically bond with the stabilizing reagent to reduce long-term mobility and toxicity.

Solidification and stabilization are often used together and co-occur depending on the type, distribution, and concentration of contaminants. These technologies slow or prevent contaminants from migrating into the surrounding environment but usually do not destroy contaminants. In-situ treatment of contaminated soil entails mixing it with solidification and stabilization reagents (e.g., Portland cement) to produce a structurally solid, relatively impermeable monolithic mass that is resistant to leaching of contaminants to groundwater. ISS can also be combined with other remedial technologies.

When used at MGP sites ISS technology is effective, typically focused on reducing mobility and/or toxicity of organic hydrocarbons (e.g. PVOCs and PAHs) and inorganic compounds (e.g. cyanide and lead). Effectiveness is limited to the percentage of free-product within the media. Mix designs vary depending on soil and subsurface conditions and most applications employ a bench scale/treatability study to demonstrate effectiveness in meeting cleanup objectives. Physical and chemical properties are assessed, such as permeability, leachability, strength, wet/dry durability, and freeze/thaw durability of the monolithic mass and volumetric expansion.

ISS monolithic material may weather or deteriorate over time, which may increase the release of contaminants to the groundwater or surface water; however, the bench scale testing program can be designed to evaluate this risk. There are no by-products generated by the implementation of this technology, however some processes can increase the volume of the treatment area substantially (typically 20% to 40%), and upfront planning to accommodate for the increase in volume is required. Also, heterogeneous subsurface, or variations in material types could limit effectiveness. The relative cost of this technology is moderate.

Soil Vapor Extraction - SVE utilizes a vacuum that is applied to extraction wells to remove gas-phase contaminants from the vadose (unsaturated) zone.

SVE is effective at recovering PVOCs and some PAHs that are present in the soil vapor in the vadose zone. SVE is not a suitable technology in the recovery of free product below the groundwater table, but it can be used to enhance other technologies used for that purpose. This technology also requires maintenance/replacement of air filter media/treatment system. High moisture in the soil requires higher vacuums and can hinder operation of system. Removal rates may be reduced by high organic content, extremely dry soil or high sorption capacity of PAHs in the soil. SVE may also require an off-gas treatment system. In addition SVE may require a pump and treat system for the groundwater in order to keep the water table from entering the vadose zone. The water/moisture often extracted during the SVE process may need to be treated or sent for proper disposal. This technology previously was used extensively which allows for a wide range of system choices and capabilities. SVE spent air filter media and water waste from this process will require proper disposal and handling. The relative cost of this technology is moderate.

Chemical and Surfactant-Enhanced Oxidation - ISCO converts contaminants to inert or less toxic compounds by injecting chemicals, sometimes enhanced with surfactants via wells within the contaminated area which are then extracted by pumping or other technologies. The most common chemicals used in ISCO are permanganate, peroxide (Fenton's reagent) and ozone.

ISCO is effective for hydrocarbons and PVOCs, but ISCO is limited in effectiveness in the recovery of DNAPL. SISCO is more effective than ISCO for heavily contaminated soil such as tar-saturated soil. The chemical reactions in ISCO provide rapid and extensive reactions with and destruction of various contaminants. ISCO is effective for many organics and subsurface environments. SISCO provides rapid and extensive reactions with and destruction of various contaminants. Surfactants assist in the separation of contaminants, such as tar, from soil particle which further assists the ISCO process.

Subsurface conditions must be well determined in order to understand potential ISCO reactions. This technology requires handling, storage, distribution, and safety precautions for the large quantities of hazardous oxidizing chemicals. Since water in the SISCO system is re-circulated through the ground and treatment system there is no by-products or generated waste. The overall effectiveness of these technologies is under study. The relative cost of these technologies is moderate to high.

Thermal Treatment - Thermal treatment raises the soil temperatures and increases the volatilization rates of PVOCs and reduces the viscosity of tar. Thermal treatment uses a heating or energy inducing method along with an extraction method, either SVE (see Section 2.4.2) and/or liquid recovery. This technology is more appropriate for conditions that involve tar saturated soil, groundwater and vadose zone contamination. It would generally not be used to address vadose zone soil alone. Steam/hot water is forced through injection wells within an aquifer to enhance vaporization of PVOCs and certain PAHs. As the vaporized compounds rise they are removed by vacuum extraction then treated. The water may be treated and reused. This technology includes Contained Recovery of Oily Waste (CROW), Steam Injection and Vacuum Extraction (SIVE), In-situ Steam-Enhanced Extraction (ISEE), and Steam-Enhanced Recovery Process (SERP).

Thermal treatment is effective for LNAPL, DNAPL, PVOCs, and certain PAHs. Thermal treatment can be used to remove large portions of oily waste accumulations and to retard downward and lateral migration of organic contaminants. This treatment technology may be used to mobilize contaminants such as oils or tars. Hot water or steam can be injected at the perimeter of a plume of tar-saturated soil and extracted from the center of the plume, which can assist in containing a moving or expanding plume. The water used and recovered can be treated and recycled through the system. This technology requires substantial and sustained heating and drying of the soil to be effective. The soil type, contaminant characteristics and concentrations, geology, and hydrogeology can significantly affect the process. This technique uses a large amount of water and can adversely affect the water table. Monitoring beyond the perimeter must occur to ensure the contaminants are not mobilizing to areas outside of the treatment zone. Dissolved iron from coal tar heating may separate and cause an increase in dissolved iron in the groundwater; a technology suitable for the recovery of the released iron in the groundwater should be considered. If water in this system is re-circulated through the ground and treatment system there are no by-products or generated waste by the implementation of this technology. However, if groundwater levels need to be controlled and water is removed, appropriate wastewater disposal would be required.

TCH is a process that uses thermal wells to apply heat to the soil from a high-temperature surface in contact with the soil, so that radiation and thermal conduction heat transfer are effective near the heater. As a result, thermal conduction and convection occur in the bulk of the soil volume between the heater wells. The application of TCH can raise the subsurface temperature to the boiling point of water, which results in effectively distilling the PVOCs and some PAHs (e.g., benzene, toluene and naphthalene) for conventional vapor recovery using an SVE system and can enhance a free-product recovery system.

TCH can also be used for In Situ Thermochemical Solidification (ISTS). ISTS is accomplished through the simultaneous application of heat (in the form of TCH) and vacuum in the form of SVE to the subsurface to attain an interwell target treatment temperature of 100°C or slightly above; thereby, volatilizing organic compounds (i.e., benzene and naphthalene) and stabilizing or solidifying any remaining tar-saturated soil in place. The effect of the ISTS is to stabilize coal tar-saturated soil in place to prevent migration, and immobilize the remaining parts of the tar as a non-leachable material resembling asphalt. Confirmation samples are required post treatment to verify that the remaining material does not have chemicals of concern leaching into the groundwater. The application of the TCH process does not create by-products or generate any additional waste. The SVE waste will need to be properly handled and disposed. The relative cost of the thermal technology is moderate to high.

2.4.3 Ex-Situ Treatment

The following ex-situ approaches have been evaluated:

- Excavation and disposal; and
- Excavation and on-site or off-site treatment using low to medium temperature thermal desoprtion.

Excavation and On or Off-Site Disposal - Excavation is a process where affected soil and surrounding soil is excavated. The soil is staged, pretreatment such as solidification or dewatering may be applied or soil from the excavation is directly loaded into trucks and sent to a permitted Treatment/Storage/Disposal (TSD) facility. This technology is effective in removing contaminated soil and addresses groundwater, tar and DNAPL as well. If a significant volume of waste is generated, landfill capacity may become an issue. If so, on-site relocation may be considered. Excavations would generally be filled with imported backfill material.

Excavation is effective for all contaminants that adsorb to the soil. This technology requires engineering, erosion and access controls during construction for managing fugitive emissions, soil, and public access. There is a moderate potential short term exposure risk (odors, and construction worker and community exposures). This technology alone does not treat the soil. Earth retention systems may be utilized to support surface and subsurface structures and utilities, or when side sloped open cut excavations are not feasible. The removal and/or treatment of surface water exposed to the excavation area may be conducted on-site or by collection and off-site disposal. Subsurface structures or above ground structures may make this technology less effective. There are often limitations based on the availability of required space for staging and handling of soil material and water treatment system, if needed. Air quality controls need to be addressed for emissions and dust. The relative cost of this technology is moderate to high.

Excavation and On or Off-Site Treatment Using Thermal Desorption - Excavation is described above. Instead of off-site disposal, a low or medium temperature thermal desorption unit may be used to thermally treat the excavated soil. The treated soil is then used to backfill the excavation. Thermal desorption can virtually destroy many PVOCs and PAHs. Obstructions are addressed through a screening process and large objects will require off-site disposal. Moisture content is critical to the process as well. Air emission limits will need to be achieved. Noise is a factor, as the unit must operate continuously in order to be efficient. A significant amount of energy is required to efficiently operate the unit. It may be advantageous to locate the treatment unit off-site (in a more spacious area, in a less noise-sensitive area or one that can be more easily permitted to operate) and transport the waste to, and the by-product back to the site.

A significant effort is required to mobilize, permit and operate the unit, and the unit treatment cost would decrease with volume. As such, the relative cost of this technology is moderate to high.

2.5 Sediment

Remedial technologies that address sediment are presented below. As discussed in the ñContaminated Sediment Remediation Guidance for Hazardous Waste Sitesò (USEPA, 2005), these technologies may be combined at a sediment site to address the varying levels of risk or conditions associated with contaminated sediment (e.g., higher-risk contaminated sediment may be dredged, depositional areas may be monitored, etc.).

2.5.1 Monitored Natural Recovery

Monitored natural recovery (MNR) relies on ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability and toxicity of contaminants in sediment. Risk reduction, due to isolation and mixing of contaminants through natural sedimentation, is the process most frequently relied upon for contaminated sediment. Enhanced MNR may be achieved through thin layers of granular material. The presence of total organic carbon and/or black carbon (either petrogenic ï naturally occurring sources, or anthropogenic ï a result of man) also reduces the mobility and bioavailability of contaminants.

MNR may include long-term monitoring to confirm predicted sediment stability through periodic bathymetric surveys. Bathymetric surveys confirm the continued isolation of underlying affected sediment, or may identify areas of erosion/scour which may need to be addressed. MNR may also include periodic sediment sampling to measure natural processes (e.g., degradation products) and burial over time. Monitoring biota is not anticipated at any of the sites because the contaminants of concern do not bioaccumulate.

To increase the effectiveness of MNR, institutional controls may be necessary. Relative costs for MNR are low to moderate.

2.5.2 Capping

Capping utilizes physical isolation of affected sediment from the aquatic environment and may incorporate stabilization and erosion protection and chemical isolation to reduce mobility of contaminated sediment. Capping minimizes resuspension and transport of contaminants. Caps are generally constructed of granular material, such as ñcleanò sediment, sand, or gravel. More complex caps may include geotextiles, impermeable liners, or other reactive elements in layers (e.g., granular activated carbon) to attenuate the flux of contaminants and reduce the bioavailability of contaminants. Caps are designed to reduced risk through three primary functions:

- Physical isolation of the contaminated sediment sufficient to reduce exposure due to direct contact and reduce the ability of burrowing organisms to move contaminants to the surface;
- Stabilization of contaminated sediment and erosion protection of sediment and cap, sufficient to reduce resuspension and transport to other sites; and/or
- Chemical isolation of contaminated sediment sufficient to reduce exposure from dissolved and colloidally-bound contaminants transported into the water column.

Caps may be designed with different layers or a single layer to serve these functions. The required cap thickness depends on contaminant type and concentration, the biologically active zone depth, sediment physical characteristics, expected sediment consolidation, and potential bed shear forces from storm events, boat propeller wash and ice.

Cap placement can be mechanical (e.g., clamshells or release from a barge) or entrained in a water slurry and discharged at the water surface or at depth. The placement method should minimize resuspension and release of contaminants during cap placement. The placement method will also need to consider water depth ï access by barge may be limited in shallow water areas.

Long-term monitoring through bathymetric surveys should be considered to verify the presence of the cap and its thickness. Cap monitoring is expected to be more intense during the first 5 years following construction, and may target extreme flow events.

Capping includes long-term monitoring of sediment stability through routine bathymetric surveys. Surveys may also target extreme flow events. The bathymetric surveys confirm cap presence and thickness (thickness derived from comparison of bathymetry to the baseline surface elevation immediately after placement, and consider potential consolidation), and identify areas which may require further assessment and/or cap maintenance. To increase the effectiveness of capping, institutional controls (i.e., no wake zones, construction limitations, etc.), may be necessary. Relative costs for capping are moderate.

2.5.3 In-Situ Treatment

In-situ treatment for sediment is an emerging technology that may involve either (i) enhanced biological or abiotic degradation or (ii) enhancing the sequestering properties of natural sediment. Of these, the most data are available for enhancing the sequestering properties of natural sediment which is further discussed below. Other in-situ treatment technologies may be identified on a site-specific basis.

In-situ treatment to enhance sequestering properties may include delivery of amendments or reagents into sediment through a variety of methods. Activated carbon or other carbon sources are the most likely amendment to be used to sequester PAH constituents in sediment. Organoclays may be useful in controlling DNAPL, if present. The dosage, targeted depth, and optimum delivery method will be evaluated on a site-specific basis. The activated carbon may be delivered through a mixed tiller (activated carbon applied to the sediment surface and mixed into sediments using a roto-tiller with rotating tines, a tine sled (activated carbon applied via injection nozzles on tine sled, pulled on the sediment surface) or an unmixed tiller (activated carbon applied to the sediment surface without mixing and benthic organisms incorporate the activated carbon). Other delivery systems may also be evaluated, such as SediMiteÊ which is an agglomerate containing treatment reagents that sink to the sediment surface and resist resuspension.

Characteristics conducive to in-situ treatment are similar to that of capping. Advantages of in-situ treatment, if adequate mixing is achieved, include:

- Leaving sediments in place so contaminants are not transferred during the remedial action and habitat may be preserved;
- Avoids extensive handling of sediment (including dewatering, trucking, and landfilling);
- Reduction in volatilization from sediment handling;
- Meets Section 121b CERCLA/SARA preference for treatment of contaminants; and
- Lower costs and implementation time.

In-situ treatment includes long-term monitoring of sediment to verify effectiveness. To increase the effectiveness of in-situ treatment, institutional controls (i.e., no wake zones, construction limitations, etc.), may be necessary. Relative costs for in-situ treatment are low to moderate.

2.5.4 Dredge/Excavate and Disposal

Dredging and excavation are common approaches to removing contaminated sediment from a water body and involves either (i) submerged sediment removal (mechanical or hydraulic ñwetò dredging) or (ii) post-water diversion removal (ñdryò excavation). Dredging or excavation approaches need to consider removal methods, transport to an upland staging and processing area, dewatering, water treatment and discharge, and transportation and disposal of the sediment.

Removal methods need to minimize and control (i) resuspension, (ii) release, and (iii) generated residuals. Resuspension refers to sediments that are disturbed during dredging and become resuspended in the water column and may be transported downstream or redeposited in place. Release refers to the dredging operations transferring contaminants from the sediment into the water column or air. Generated residuals refer to contaminated post-dredging surface sediments that are dislodged or suspended by the dredging operation are subsequently redeposited on the bottom of the water body. Generated residuals are different than undisturbed residuals. Undisturbed residuals may be uncovered during dredging but not fully removed. Experienced marine contractors using best management practices and proper design minimize resuspended and generated residuals. Adequate sediment characterization and design plans minimize undisturbed residuals.

After removal, the new sediment surface may be backfilled, restoring the river to the original bathymetry, or covered with a sand blanket to manage generated residuals. Dredged areas may also be capped, depending on the remaining concentrations and site conditions.

Removed sediment is often transported to a staging or rehandling area for dewatering (if necessary) and further processing, treatment, or final disposal. Transportation methods include pipeline, barge, conveyor, railcar, or truck/trailer. The degree of dewatering and treatment depends on the sediment conditions, the contaminants and concentrations, and volume of material to be handled. Treatment options (other than dewatering), if used, are generally classified as biological, chemical, extraction, immobilization, and thermal. Once dewatered (and possibly treated), dredged materials must be properly disposed either on- or off-site.

Dredging/excavating does not include long-term monitoring if the affected sediment is removed. Relative costs for dredging are moderate to high.

2.6 DNAPL

DNAPL is identified as free-product that is separated from tar saturated soil. It can also include tar in the vadose zone in the form of tar in structures, separate phase tar at the ground surface and in other forms. Many of the in-situ treatment technologies discussed under soil do not necessarily apply to this definition of DNAPL except in the sense that any liquid that is captured within the soil would be addressed by the in-situ technologies evaluated for soil in Section 2.4. These technologies will not be discussed again in this section.

Remedial technologies that address DNAPL in a mostly liquid form can be divided into three general response actions including:

- Containment;
- DNAPL or free product recovery; and
- Enhanced DNAPL recovery.

As discussed in Section 2.3, it may be necessary to replace standard schedule 40 polyvinyl chloride (PVC) constructed groundwater monitoring wells with other chemically resistant groundwater monitoring well materials (e.g. stainless steel) if the PVC wells become damaged as a result of significant volumes of NAPL in the subsurface. Replacement wells will be installed on a site-specific basis as part of long-term monitoring plans in areas of NAPL plumes, as necessary. In addition, construction materials for NAPL recovery wells (discussed below) will be evaluated for chemical compatibility as part of the design plans.

2.6.1 Containment

The following remedial technologies and process options address containment of DNAPL.

- Physical Barriers; and
- Capping/ Engineered Barriers.

Physical Barriers - As discussed under groundwater in Section 2.3, physical or subsurface barriers are often composed of sheet piling, HDPE or soil, bentonite and concrete slurry walls. The barriers are used to contain and/or divert DNAPL and tar away from sensitive areas such as the zone of capture for drinking water wells or to collection sumps. The vertical barriers are keyed into an underlying impervious geologic unit to prevent lateral migration.

Physical barriers are effective at containing, diverting and/or isolating free product and DNAPL. Barriers are often combined with other technologies in order to effectively capture the DNAPL prior to treating the area with in-situ treatment technologies. It can also be used to capture DNAPL for extraction and ex-situ treatment. The physical barrier's wall composition may degrade, deteriorate, or be damaged by nearby activity. As a result, physical barriers may require continued monitoring inside and outside the wall for potential leakage from the containment area. The relative cost of this technology is moderate.

Capping/Engineered Barriers ï Surface caps include using a selected thickness of soil or aggregate to provide a barrier, asphalt or concrete to provide an impervious barrier, and geosynthetic covers (or geosynthetics combined with earthen materials) to provide caps that are impervious and include drainage layers and redundancy. Caps are used for creating a physical barrier separation between the DNAPL and the surface.

Capping/engineered barriers do not treat the DNAPL, but enables the isolation of DNAPL, provided they do not deteriorate. Impervious barriers on top of a DNAPL also prevent continued migration of contaminants from the DNAPL to the underlying groundwater due to incidental precipitation. Multi-layered caps may include redundancy by using soil and a geosynthetic liner, or another combination of materials to provide increased protection. Capping material composition may degrade, deteriorate, or be damaged. In addition, the capping material degradation may occur naturally over time. This technology may require continued monitoring in the capped areas to identify potential cap or barrier degradation. The relative cost of this technology is low to moderate, depending on the aerial extent.

2.6.2 DNAPL or Free Product Recovery

Free product recovery removes DNAPL from the substrate by active (pumping) or passive collection systems. The DNAPL enters recovery wells, sumps or trenches that are pumped on some schedule. Recovered DNAPL is managed and disposed of off-site.

Free product recovery is effective for the removal of DNAPL, although it generally is a very long-term process at MGP sites. This technology can effectively reduce the quantity of DNAPL which may be difficult to remove through other remedial technologies. Since DNAPL tends to adhere to soil particles, free product removal or pumping leaves behind residual contaminants, which are discussed above in Section 2.4. This technology was extensively used in the past which allows for a wide range of system choices and capabilities. The relative cost of this technology is low to moderate, provided the recovery method utilizes a passive system.

2.6.3 Enhanced DNAPL or Free Product Recovery

This technology involves mechanically altering the physical properties of free product to enhance movement and recovery. MGP tar is very viscous and must be heated in order to decrease this viscosity. Two types of enhancement are discussed below.

Pressure Pulse Technology - PPT is a process using a hydraulic pulse to create high pressure intervals at or near the water table to increase mobility and flow of contaminants. The PPT system may include a SVE and/or a well extraction system to extract the contaminants.

PPT technology is used in the petroleum industry to increase movement of oil for greater recovery. PPT is very effective for NAPL and DNAPL. This technology may be used to enhance other remediation technologies such as pump and treat, bioremediation, PRBs, and thermal heating. The main application difference for the use of PPT in the petroleum industry is the deep hydrogeologic formations which differ greatly from the much shallower depth for remediation applications. Subsurface conditions must be known for PPT to be effective.

This technology was extensively used in the past which allows for a wide range of system choices and capabilities. However, most applications are in the petroleum industry and limited use for remediation. The PPT system does not create any by-products or generated waste, however SVE spent air filter media and groundwater collection from a pump and treat system does generates waste. The relative cost of this technology is moderate to high.

Electrical Resistance Heating - ERH uses electrodes to produce a current to heat the DNAPL. The DNAPL is heated, viscosity is decreased and the DNAPL is readily recovered.

ERH is effective for enhancing DNAPL recovery. The subsurface conditions must be well known and mapped. Buried metal probes and high voltages require extra safety precautions and barriers to prevent exposure. This technology was extensively used in the past which allows for a range of system choices and capabilities. The application ERH does not create any by-products or generate waste, however, it does not reduce the volume of DNAPL - it only enhances the recovery. The relative cost of this technology is moderate to high.

2.7 Vapor Intrusion

Vapor intrusion describes the process where vapors are released from subsurface contamination and intrude into buildings and other existing structures that lie over the contaminated subsurface soil or a plume of contaminated groundwater. At MGP sites, benzene and naphthalene are the primary COPCs that may present an issue, although other COPCs may also be present, depending on site-specific constituents. If no soil or groundwater contamination is present, or if no plume of contaminated groundwater is moving toward or under an existing building, then vapor intrusion is not an issue.

Vapor attenuates as it rises to the surface and floor slabs prevent the vertical migration of the vapors. Cracks in floor slabs may provide a pathway for the vapors.

2.7.1 Active Mitigation

The following technologies address active mitigation of vapor intrusion:

- ý Soil and/or Groundwater Remediation ï If contaminated soil and/or groundwater is removed, then no vapor intrusion should occur;
- ý Sub-slab (or sub-membrane) Pressurization or Depressurization ï if soil and/or groundwater contamination is causing intrusion of vapors, then the building structure can be modified to prevent potential intrusion; and
- ý Building Pressurization.

Soil and/or Groundwater Remediation - Soil and/or groundwater remediation utilizes a vast array of remedial technologies to remove the source of contamination or plume located under a building. The primary objective is to remove the potential contaminants and thus the source of soil gas that could enter into an above ground structure constructed over potentially contaminated soil or over or downgradient of a plume of contaminated groundwater.

Soil and/or groundwater remediationös effectiveness depends on the technology used and the success at removing the potential contaminants from releasing soil vapors. The relative cost of soil and/or groundwater remediation is discussed in Sections 2.3 and 2.4, respectively.

Sub-slab (or sub-membrane) Pressurization or Depressurization – A sub-slab (or sub-membrane) pressurization process is operated by fans or blowers that draw air from outside and are directed to under the buildings' slab or membrane to create a positive pressure under the building. This positive pressure displaces potential soil gas from rising up into the building by creating a pressure barrier.

The most common soil vapor action mitigation approach is sub-slab (or sub-membrane) depressurization. An electric powered motor fan is used to draw in air and soil gas beneath the slab or membrane (typically HDPE) and exhaust the gases above and outside the building. Air and soil vapors migrate to the negative draw from the exhaust system.

Sub-slab (or sub-membrane) pressurization or depressurization is an effective mitigation technology for benzene and naphthalene. The system effectiveness is reduced if slab or membrane integrity is compromised. Saturated and low-permeable soils reduce gas movement often requiring more exhaust/blower units to the system. Pressurization often requires a larger system and energy costs compared to depressurization. Filters, if applicable, to the exhaust/blower will require maintenance and replacement as needed to maintain efficient operation. This technology is easily implemented for retro-fitting existing buildings. Sub-slab (or sub-membrane) pressurization or depressurization requires monitoring and maintenance to ensure continued motorized fan operation. Subsurface conditions and soil properties should be known to design a system that creates proper pressurization or depressurization. The system will require periodic inspection to confirm a tight seal and no leaks in the slab or membrane. There are typically no by-products or generated waste by the implementation of these technologies, however if filter media is used in the depressurization process, then waste will be generated. The relative cost of this technology is low to moderate.

Building Pressurization - Building pressurization is a process where the buildings Heating, Ventilation and Air Conditioning (HVAC) system is optimized to create a positive building pressure relative to the sub-slab pressure. The buildingọs positive pressure displaces potential soil gas from rising up into the building by creating a pressure barrier.

Building pressurization is an effective mitigation technology for benzene and naphthalene. The system effectiveness is achieved through a relatively small increase in the building pressure. Proper air balancing is necessary to assure positive pressure throughout the lowest level of the building. This technology requires periodic maintenance and pressure tests to sustain proper positive pressure. Often HVAC systems are turned off or reduce operations during weekends and off-peak usage times. This reduced operation can cause pressure equalization in the building, reducing or eliminating the effectiveness of a positive building pressure mitigation approach. System designs need to account for pressurization during these off-peak times. This technology is easily implemented to retro-fit existing buildings. This technology also requires monitoring and maintenance to ensure continued HVAC positive pressure in the building. The HVAC system capabilities should be known in order to design/retro-fit a system that creates proper building pressurization. In addition, the buildingôs slab and/or membrane should be sealed to increase the efficiency of the system. There are no by-products or generated waste by the implementation of this technology. The relative cost of this technology is moderate.

2.7.2 Passive Mitigation

The following technologies address passive mitigation:

- Sub-slab Barriers; and
- Passive Venting.

Sub-slab Barriers - Sub-slab barriers such as HDPE liners or spray-on asphalt sealants are used create an impenetrable layer that soil gases cannot pass through. These barriers are easily installed at new construction buildings but often difficult and costly for existing buildings. Often sub-slab barriers are used in conjunction with passive venting or active mitigation approaches such as sub-slab depressurization.

Sub-slab barriers offer a moderate effective mitigation technology for benzene and naphthalene. The system effectiveness is dependant on the initial and long-term air tight seal of the barrier. Efficiency greatly decreases as deterioration, punctures, or incomplete seals in the barrier system allows for soil gas to enter into the building. If the barriers seal is compromised and retro-fitting efforts fail, then active mitigation approaches will need to be investigated. Pressure tests can be conducted to verify system effectiveness. Sub-slab barriers can be easily implemented for new construction but often very difficult for retro-fitting existing buildings. This technology requires monitoring to ensure continued sub-slab barrier integrity. Care must be taken when the system is installed so that building construction continues to maintain the integrity and seal of the system. Often sub-slab barriers are installed in conjunction with other technologies such as passive venting and should be designed to allow for these other systems. There are no by-products or generated waste by the implementation of this technology. The relative cost of this technology for new construction compared to the other passive mitigation alternatives is low, but can be high for existing structures.

Passive Venting - Passive venting utilizes a sub-slab barrier (to keep soil gasses from migrating into the building), a system of venting layers (often sand, gravel, or other high permeable aggregate with very low abrasive characteristics so as to not damage any sub-slab barriers), and a venting area where a vent pipe goes from the sub-slab area to an outside location. The passive system allows lateral migration of soil gases to venting areas by natural pressure gradients and the exhausting of gas vapors without mechanical processes.

Passive venting is almost exclusively utilized in conjunction with a sub-slab barrier system. Passive venting is a moderately effective mitigation technology for benzene and naphthalene. The system effectiveness is dependant on the initial and long-term air tight seal of the sub-slab barrier and the natural conditions of the soil, venting layers, and outdoor conditions. The system efficiency decreases as deterioration, punctures, or incomplete seals in the sub-slab barrier system allows for soil gas to enter into the building instead of flowing to the passive venting system. In addition, efficiency decreases when outside conditions such as cold temperatures and low winds reduce suction and naturally drafting methods for the passive venting system. The system effectiveness comparable to active systems can be achieved by increasing the number of venting areas, larger and more permeable venting layers, and insulating vent pipes. Pressure tests can be conducted to verify system effectiveness. Passive venting is easily implemented for new construction but often very difficult for retro-fitting existing buildings. This technology requires monitoring to ensure continued sub-slab barrier integrity and proper venting. Passive venting systems can often be designed to allow for future retro-fitting to an active venting system. The sub-slab soil conditions should be well known and an adequate venting layer of permeable material should provide for easy natural migration of soil gas. There are no by-products or generated waste by the implementation of this technology. The relative cost of this technology compared to the other passive mitigation alternatives is low for new construction, and high, but can be high for existing structures.

3 PRELIMINARY LIST OF POSSIBLE ARARS

This section identifies possible ARARs and guidance to be considered (TBCs) in selecting remedial technologies. Table 1 summarizes preliminary federal and state (Illinois and Wisconsin) ARARs and TBCs. The ARARs and TBCs may be modified in the Site-Specific FS and until a Record of Decision (ROD) is issued. ARARs and TBCs may also be reexamined during the five-year review process.

Section 121 of CERCLA requires, subject to specified exceptions, that remedial actions must be protective of human health and the environment. In addition, remedial actions performed under the Superfund program must be undertaken in compliance with both state and federal ARARs. ARARs are defined as:

> *Any cleanup standards, standard of control, environmental protection requirements, criterion, or limitation under any Federal or State environmental law that specifically addresses a hazardous substance, pollutant, contaminant, remedial action, or location*.

Promulgated State Standards that are more stringent than the Federal Standards may be an ARAR. In addition to ARARs, the USEPA may identify other relevant information, criteria, or guidance TBC. TBCs may not be legally binding or enforceable but may be useful in developing remedial alternatives. Both ARARs and TBCs may be chemical-specific, location-specific, or action-specific.

Chemical-specific ARARs are generally health or risk based standards that define concentration limits for environmental media or discharges. These requirements may be used to identify PRGs for constituents of concern in environmental media.

Location-specific ARARs are based on the siteòs characteristics or location including natural site features such as wetlands, floodplains, and endangered or threatened species and habitats. Location-specific ARARs may also apply to man-made features such as cultural resource areas.

Action-specific ARARs are technology-based or activity-based limits that guide how the remedial action will be implemented or how remedial waste may be handled.

4 PRELIMINARY PERMITTING/EQUIVALENCY REQUIREMENTS

This section discusses the permitting/equivalency requirements for the possible ARARs and guidance TBC identified in Section 3. Table 1 provides a summary of the permitting requirements for ARARs and TBCs that may be applicable to remedial actions performed at the former MGP sites. As discussed in Section 3, these ARARs and TBCs are preliminary and may by revised until the ROD is signed or if newly-promulgated requirements or other information is identified during the five-year reviews.

CERCLA response actions are exempted by law from the requirement to obtain Federal, State or local permits related to any activities conducted on-site (CERCLA Section 121(e)(1)). However, remedial activities must meet (or waive) the substantive provisions of permitting regulations that are ARARs. To demonstrate compliance with ARARs, a permit equivalency process is followed. Under the equivalency process, IBS would pursue to secure a permit, except most fees and public hearing requirements would be waived to minimize delays. Through this process, state and local agencies provide useful information in determining ARARs, although USEPA makes the final decision.

At USEPAõs discretion, the equivalency process may not be implemented because actual permits are not required under CERCLA and procedural requirements are not ARARs under CERCLA Section 121 (d)(2). Whether the equivalency process is implemented or not, the remedy will meet all of the substantive requirements of the permitting regulations that are ARARs.

In accordance with CERCLA Section 121 (d)(4), USEPA may select a remedial action that does not meet an ARAR under any one of 6 waiver circumstances. If waivers from any ARARs are involved, the USEPA is responsible for ensuring that the conditions of the waivers are met. If waivers are to be considered, the USEPA will provide the State agencies an opportunity to provide comments.

5 SITE-SPECIFIC FEASIBILITY STUDY SCOPE OF WORK

This section identifies the approach to the FS on a site-specific basis for Former MGP Sites. The FS will be completed in accordance with the guidelines presented in the RI/FS Guidance Document (USEPA 1988). Additional guidance may be identified as part of future discussions with USEPA during scoping meetings to prepare the Site-Specific FS memorandum and documents included in the SOW.

Multi-Site FS Documents include:

- Preliminary Remedial Technology Screening (SOW Task 1.2.2.1);
- Preliminary List of Possible ARARs (SOW Task 1.2.2.2); and
- Preliminary Permitting/Equivalency Requirements (SOW Task 1.2.2.3).

On a site-specific basis, it may be reasonable to combine technical memorandums on the development and screening of alternatives with the detailed analysis of alternatives. On a site-specific basis, elements of the technical memorandums may be presented in the FS Report and may be further streamlined (e.g., a minimal number of alternatives have been assembled and each will be further evaluated in the detailed analysis of alternatives/nine criteria, rather than preliminary evaluation of alternatives based on effectiveness, implementability and cost).

5.1 Development and Screening of Alternatives

Task 6 of the SOW requires a range of site-specific remedial alternatives be developed and screened for evaluation in the FS. The site-specific remedial alternatives will build on the Multi-Site FS Documents. A Site-Specific Alternatives Screening Technical Memorandum will be prepared to summarize the site-specific alternative array analysis. The memorandum will document the methods, the rationale and the results of the alternatives screening process and will include the following elements:

5.1.1 Development of Remedial Action Objectives

Remedial action objectives will be developed based on the results of the human health and ecological risk assessments. Prior to developing these objectives, the contaminants and media of concern, potential pathways, and contaminant level or ranges that are protective of human health and environment will be specified. The remedial response objectives that may be developed will focus on eliminating or minimizing substantial risks to human health and the environment.

5.1.2 Identify Areas or Volumes of Media

The areas and/or volumes of media in which response actions may apply will be delineated and will consider the requirements for protectiveness as identified in the remedial action objectives. These areas and/or volumes of media addressed will form the foundation for developing and screening remedial technologies.

5.1.3 Identify, Screen, and Document Remedial Technologies

Applicable technologies, identified in Section 2, will be identified and evaluated to eliminate technologies that cannot be implemented technically at a Site. This screening will be accomplished by first evaluating technologies on the basis of effectiveness, implementability, and cost. Retained technologies will be assembled in remedial alternatives for further analysis.

The effectiveness evaluation will consider the effectiveness of a technology process relative to other processes within the same technology type. The evaluation will focus on the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals, the potential impacts to human health and the environment **during** the remediation phase and how proven and reliable the process is with respect to the contaminants.

The implementability evaluation will be used to measure both the technical and administrative feasibility of implementing a technology process. Items such as the ability to obtain necessary permits for off-site actions, the availability and capacity of treatment, storage and disposal services and the availability of equipment and skilled workers will be evaluated.

The cost evaluation will include relative estimates of capital costs and annual operation and maintenance (O&M) cost. These conceptual cost estimates are order-of-magnitude estimates, and will be prepared based on preliminary conceptual engineering for major construction components and unit costs of capital investment and general O&M costs available from USEPA guidance documents or past experience with similar systems/projects. Processes are evaluated as to whether costs are high, medium or low relative to other process options in the same technology type.

5.1.4 Assemble and Document Alternatives

A draft remedial alternatives screening technical memorandum for the FS will be prepared that will document the preliminary FS work tasks described above and will address each affected medium or operable unit. A draft memorandum will be submitted to USEPA for review and comment, summarizing the results of the preliminary screening. The list of potential remedial technologies developed above will be assembled into remedial alternatives. The initially assembled remedial alternatives will undergo preliminary screening (effectiveness, implementability, and cost) to reduce the number of alternatives for future analysis while preserving a range of options, if necessary. In addition, the ARARs associated with each of the assembled alternatives will be summarized.

5.2 Detailed Analysis of Alternatives

Task 7 of the SOW requires a detailed analysis of remedial alternatives be presented to USEPA for use in selecting the Site remedy. This analysis will use the Multi-Site FS documents as the framework.

The remedial alternatives that pass the initial screening will be further evaluated. The detailed evaluation will include an analysis of each remedial option against nine evaluation criteria as set forth in 40 C.F.R. § 300.430(e)(9)(iii). These nine criteria include:

<u>**Threshold Criteria**</u>

- **Overall Protection of Human Health and the Environment** ï Assess whether each remedial alternative meets the remedial action objective that it is protective of human health and the environment. The overall assessment of protection is based on several factors assessed under the evaluation criteria, including long term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

- **Compliance with ARARs** – Evaluate how each alternative complies with applicable or relevant and appropriate Federal and State requirements and TBCs.

Balancing Criteria

- **Long-Term Effectiveness and Permanence** – Assesses the remedial action in terms of the risk remaining at the Site after the response objectives have been met. The assessment focuses on evaluating the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes and is based on the magnitude of remaining risk and the adequacy, suitability and long-term reliability of management controls to provide continued protection from residuals.

- **Reduction of Toxicity, Mobility and Volume through Treatment** – Addresses the preference for selecting remedial actions that include treatment technologies to permanently and significantly reduce toxicity, mobility or volume of contaminants. Factors to be considered include treatment processes selected, the volume of material to be treated/destroyed, the degree of reduction in toxicity, mobility or volume, and the type/quantity of treatment residuals.

- **Short-Term Effectiveness** – Assesses the effects of the alternative during the construction and implementation phase until the remedial actions have been completed and protection is achieved. The assessment considers the effects on the community and on-site workers during the remedial action, environmental impacts during implementation, and the amount of time until protection is achieved.

- **Implementability** – Addresses the technical and administrative feasibility of implementing an alternative and availability of services and materials to implement the remedy. Technical feasibility considers construction, operation, reliability, flexibility for future remedial action (if necessary), and the ability to monitor performance. Administrative feasibility considers coordination with agency groups, permitting, and approvals.

- **Cost** – Addresses the capital costs, annual O&M costs, and present worth analysis. Capital costs include direct (equipment, labor and materials) and indirect (engineering, financial and other services required to complete remedial actions) costs. Annual O&M costs are post-construction costs to ensure the on-going performance of the remedial action. Remedial action cost estimates will be compared using present work analysis to reflect future expenses in present day dollars.

Modifying Criteria

- **Agency Acceptance** – Compares the technical and administrative issues and concerns of each alternative presented. Agencies may include USEPA, Illinois Environmental Protection Agency, Wisconsin Department of Natural Resources, and the State Departments of Health.

- **Community Acceptance** – Addresses the community's concerns into the evaluation of remedial alternatives. It is anticipated the focus on community concerns will be on short-term impacts during remedial action and potential reuse scenarios. Community acceptance may be reevaluated as necessary during public comment on the FS.

5.2.1 Compare Alternatives Against Each Other and Document the Comparison of Alternatives

After the remedial alternatives have been assessed against the evaluation criteria, a comparative analysis will be performed. This analysis will compare all of the remedial alternatives against each other for each criterion. USEPA will identify and select the preferred alternative.

5.2.2 Alternatives Analysis for Institutional Controls

Alternatives that rely on institutional controls will be evaluated using the following criteria:

<u>Threshold Criteria</u>

- **Overall Protection of Human Health and the Environment** – Includes specific institutional control components that will ensure the alternative will remain protective and describes how theses specific control will meet remedial action objectives.

- **Compliance with ARARs** – Evaluates how each institutional control complies with applicable or relevant and appropriate Federal and State requirements.

<u>Balancing Criteria</u>

- **Long-Term Effectiveness** – Assesses the adequacy and reliability of institutional controls and how long the institutional control must remain in place.

- **Short Term Effectiveness** – Assesses the amount of time it will take to impose an institutional control.

- **Implementability –** Includes research and documentation that the proper entities (e.g., potentially responsible parties, state, local government entities, local landowners, conservation organizations) are willing to enter into any necessary agreement or restrictive covenant with the proper entities and/or that laws governing the restriction exist or allow implementation of the institutional control.

- **Cost –** Includes the cost to implement, maintain, monitor and enforce the institutional control.

Modifying Criteria

- **State and Community Acceptance -** Addresses the community's concerns into the use of institutional controls. Community acceptance may be reevaluated as necessary during public comment on the FS.

5.3 FS Report

A Draft FS Report will be prepared to summarize the activities performed and to present the results and associated conclusions for the tasks performed. The report will include a summary of the initial screening study process and present the detailed analysis of remedial alternatives considered as basis for developing a ROD.

It is anticipated the FS Report will contain the following sections:

- Introduction and Site Background;
- Development of Remedial Action Objectives and General Response Actions;
- Identification and Screening of Remedial Technologies;
- Development and Initial Screening of Remedial Alternatives;
- Detailed Analysis of Alternatives;
- Comparative Analysis of Alternatives; and
- Summary.

The feasible technology options for site remediation, if warranted, will be identified for each general response action, and the results of the remedial technologies screening will be described. Remedial alternatives will be developed by combining the technologies identified in the previous screening process. The results of the initial screening of remedial alternatives, with respect to effectiveness, implementability and cost will be described, if appropriate on a site-specific basis. Final screening against the nine comparative criteria and the comparison of remedial alternatives will be presented with a final recommended remedial alternative. A description of the key requirements for alternative implementation and estimated time frame for construction of the final recommended alternative will also be presented in the summary and conclusions section of the report.

6 REFERENCES

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TABLES

Table 1 – Preliminary List of Applicable or Relevant and Appropriate Requirements
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

Chemical-Specific ARARs/TBC

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	REQUIREMENT/COMMENTS
ILLINOIS				
Groundwater Quality Standards	415 ILCS 55, 35 Ill. Admin. Code (IAC) 620	Groundwater	ARAR	Establishes groundwater quality standards; Class I standards are equivalent to federal Safe Drinking Water Act Maximum Contaminant Levels
Soil Cleanup Standards	415 ILCS 5/58, 35 IAC 742	Soil	TBC	Provides guidance on development of generic, site-specific and performance-based soil cleanup levels
Hazardous Waste	415 ILCS 5/22.4, 35 IAC 720-729	Soil, Groundwater	ARAR	Applies generally to treatment, storage and disposal of hazardous wastes; potential ARAR for management of contaminated media containing hazardous waste during remedial action
Air Quality Standards	415 ILCS 5/10, 35 IAC 212, 218, 243	Air	ARAR	Establishes air quality standards; potential ARAR for control of emissions or dust from management of contaminated media during remedial action
Control of Organic Compound Emissions	415 ILCS 5/10, 35 IAC 218	Air	ARAR	Establishes standards and limitations for emissions of organic material and volatile organic material from stationary sources; potential ARAR for emissions of organic compounds from management of contaminated media during remedial action
Surface Water Quality Standards	415 ILCS 5/13, 35 IAC 302-303	Sediment	TBC	Establishes surface water quality standards; TBC with respect to sediment
WISCONSIN				
Groundwater Quality Standards	Wis. Admin. Code (WAC) ch. NR 140	Groundwater	ARAR	Established groundwater quality standards, NR 140 enforcement standards equivalent to federal Safe Drinking Water Act maximum contaminant levels (MCL)
Soil Cleanup standards	WAC chs. 720 and 722; Wisconsin Guidance for Generic Soil PAH Cleanup Levels, WDNR PUBL-RR-5A-97, April 1997	Soil	TBC	Includes generic site specific, and performance-based soil cleanup standards; protects against groundwater contamination and direct contact exposure
Hazardous Waste	WAC chs. NR 660-679	Soil, Groundwater	ARAR	Applies generally to the treatment, storage and disposal of identified hazardous wastes; potential ARAR for management of contaminated media
Air Quality Standards	Wis. Stat. ch. 285; WAC chs. NR 404-415, 419, 431, 440, 445	Air	ARAR	Establishes air pollution control standards for removal, treatment and disposal of contaminated sediments and surface water; includes control of dust or emissions from treatment systems, grading or other earth work
Control of Organic Compound Emissions	WC § NR 419.07	Air	ARAR	Applies to all facilities and procedures used to remediate or dispose of soil or water contaminated with organic compounds which are direct air contaminant sources to their owners and operators

Table 1 – Preliminary List of Applicable or Relevant and Appropriate Requirements
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	REQUIREMENT/COMMENTS
Sediment Quality	WAC chs. NR 105 – 106; WDNR Guidance Document: "Assessing Sediment Quality in Water Bodies Associated with Manufactured Gas Plant Sites" (WDNR PUBL-WR-447-96, March 1996); Contaminated Sediment Quality Guidelines, WDNR PUBL-WT-732, December 2003	Sediment	TBC	DNR guidance document provides framework for investigating potential sediment contamination at MGP sites.
Surface Water Quality Standards	Wis. Stats. Ch 281; WAC chs. NR 102– 105, 207	Sediment	TBC	WQS applies to surface water; with respect to sediment, a TBC (WQS applicable to point source discharges are addressed as Action –specific ARARs)
Federal				
Resource Conservation and Recovery Act (RCRA)	40 C.F.R. § 260 et seq. – waste characterization and handling requirement Land disposal restrictions (40 C.F.R. § 268)	Soil, Groundwater	ARAR	Establishes standard for hazardous waste characterization, storage, treatment and disposal; removed materials may be subject to RCRA requirements if hazardous waste
Clean Air Act (CAA)	Air Quality Standards (40 C.F.R. § 50)	Air	ARAR	Establishes federal standards for various pollutants from mobile construction/remediation sources
Clean Water Act (CWA) (Section 304)	Water quality standards (40 C.F.R. 21 131) Discharge of dredge/fill material (33 C.F.R. § 3223) Federal Total Maximum Daily Loads (TMDLs) for impaired waters (40 C.F.R. § 130.7)	Surface Water	TBC	Federal WQS are ARARs for point source discharges where state has not adopted standards. Federal WQS are TBC for Wisconsin and Illinois as Wisconsin and Illinois have adopted WQS applicable to point source discharges from remedial action

Table 1 – Preliminary List of Applicable or Relevant and Appropriate Requirements
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

Location-Specific ARARs/TBC

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	REQUIREMENT/COMMENTS
ILLINOIS				
None				
WISCONSIN				
Water Quality Standards for Wetlands	Water Quality Standards for Wetlands (WAC ch. NR 103)	Wetlands	ARAR	Establishes water quality standards for wetlands; applicable to all determinations that affect wetlands
FEDERAL				
National Environmental Policy Act (NEPA)	Floodplain Management Executive Order 11988 (40 C.F.R. Part 6, App. A)	Floodplains	ARAR	Regulates construction in floodplains and evaluates adverse effects associated with direct/indirect development of floodplains
CWA and NEPA	Wetlands: Permits for Dredge and Fill (CWA Section 404; 33 C.F.R. Part 330); Protection of Wetlands Executive Order 11990 (40 C.F.R. Part 6, App. A)	Wetlands	ARAR	Regulates construction/remediation in wetlands; requires that no activity that adversely affects a wetlands shall be permitted if a practicable alternative that has less effect is available
Fish and Wildlife Coordination Act	16 U.S.C. §§661-677e	Surface water body modification; endangered species; migratory species	TBC	Requires coordination/consultation with Federal and State agencies to provide protection of fish and wildlife from actions that affect species and habitat; requires consultation with U.S. Fish and Wildlife Service prior to water body modification
Endangered Species Act (ESA)	Species/habitat protection (50 C.F.R. Parts 17 and 402)	Endangered/ threatened Species and habitat	ARAR	Applies if threatened and/or endangered species are present in vicinity of site

Table 1 – Preliminary List of Applicable or Relevant and Appropriate Requirements
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

Action-Specific ARARs

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	REQUIREMENT/COMMENTS
ILLINOIS				
Water Quality Standards (WQS)	415 ILCS 5/13, 35 IAC 302-303	Surface Waters	ARAR	Establishes surface water quality standards; potential ARAR for point source discharges occurring during remedial action
Miscellaneous Structures in Navigable Waters	615 ILCS 5/4.9, 17 IAC 3700-3708	Surface waters; sediment	ARAR	Imposes restrictions and conditions on construction and dredging activities in navigable waterways; potential ARAR for construction and dredging activities occurring during remedial action involving sediments
National Pollutant Discharge Elimination System (NPDES)	415 ILCS 5/13, 35 IAC 309	Surface Waters	ARAR	Requires compliance with permit limitations for discharges to navigable waterways; potential ARAR for point source discharges occurring during remedial action
Solid Waste Management	415 ILCS 5/22, 35 IAC 807-832	Solid Waste	ARAR	Applies generally to the storage, transportation and disposal of solid wastes; potential ARAR for management of media containing non-hazardous waste during remedial action
Hazardous Waste Management	415 ILCS 5/22.4, 35 IAC 720-729	Hazardous Waste	ARAR	Applies generally to treatment storage and disposal of hazardous wastes; potential ARAR for management of media containing hazardous waste during remedial action
Groundwater Protection Standards	415 ILCS 30, 77 IAC 920; 415 ILCS 55, 35 IAC 620	Groundwater	ARAR	Potential ARAR for the design, construction, installation, abandonment and documentation of groundwater monitoring wells
Soil Cleanup Requirements	415 ILCS 5/58/ 35 IAC 742	Soil	TBC	Provides generic, Site-specific and performance-based guidance on development of soil cleanup levels
WISCONSIN				
Water Quality Standards (WQS)	Wis. Stats. Ch. 281; WAC chs. NR 102-105	Surface Waters	ARAR	Establishes surface water quality standards; potential ARAR for point source discharges occurring during remedial action
Water Quality Analytical Test Methods	WAC ch. NR 219	Surface Waters	ARAR	Establishes analytical test methods applicable to effluent limitations for discharges from point sources
Miscellaneous Structures in Navigable Waters	Wis. Stats. Ch 30; WAC ch. NR 329	Surface Waters; Sediment	ARAR	Imposes restrictions and conditions on construction and dredging activities in navigable waterways; potential ARAR for construction and dredging activities occurring during remedial action involving sediments
Wisconsin Pollutant Discharge Elimination System (WPDES)	Wis. Stat. Ch. 283; WAC chs. NR 102, 104, 105, 106, 200, 207, 219, 220	Surface Waters	ARAR	Requires compliance with permit limitations for discharges to navigable waterways; potential ARAR for point source discharges occurring during remedial action
Solid Waste Management	Wis. Stat. ch. 289; WAC chs. NR 500-590	Soil	ARAR	Applies generally to the storage, transportation and disposal of solid wastes; potential ARAR for management of media containing non-hazardous waste during remedial action

Table 1 – Preliminary List of Applicable or Relevant and Appropriate Requirements
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	REQUIREMENT/COMMENTS
Hazardous Waste Management	Wis. Stat. ch. 291; WAC chs. NR 661, 662, 664	Soil, Groundwater	ARAR	Applies generally to treatment storage and disposal of hazardous wastes; potential ARAR for management of media containing hazardous waste during remedial action
Groundwater Protection Standards	Groundwater Monitoring Well Requirements (WAC ch. NR 141)	Groundwater	ARAR	Potential ARAR for the design, construction, installation, abandonment and documentation of groundwater monitoring wells
Soil Cleanup Requirements	WAC ch. NR 720	Soil	TBC	Provides generic, Site-specific and performance-based guidance on development of soil cleanup levels
FEDERAL				
CWA	National Pollutant Discharge Elimination System (NPDES)	Surface Waters	ARAR	Potential ARAR for any wastewater discharge of treated groundwater during course of remediation; establishes criteria and standards for imposing treatment requirements in permits
CWA (Section 304)	Ambient Water Quality Criteria (40 C.F.R. Part 130)	Surface Waters	ARAR	Ambient Water Quality Criteria for the protection of aquatic life and human health potential ARAR for discharging treated water to a navigable waterway
RCRA	Hazardous Waste Management System-General (40 C.F.R. Part 260) and Identification and Listing of Hazardous Waste (40 C.F.R. Part 261)	Soil	ARAR	Identifies solid wastes subject to regulation as hazardous wastes and provides general standards for handling and disposal of hazardous wastes
RCRA	Standards for Hazardous Waste Generators (40 C.F.R. Part 262)	Soil	ARAR	General requirements for packaging, labeling, marking, and manifesting RCRA hazardous wastes for temporary storage and transportation off-site
RCRA	Municipal Solid Waste Landfills (40 C.F.R. Part 258)	Offsite land disposal non-hazardous waste	ARAR	Applicable to remedial actions that involve generation of non-hazardous waste minimum national criteria for management on non-hazardous waste
U.S. Department of Transportation	Hazardous Waste Transport (49 C.F.R. Parts 107, 171 and 172)	Offsite land disposal hazardous waste	ARAR	Applies to transportation, packaging and labeling of hazardous materials on public roadways

Table 2 - General Response Options
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action	Remedial Technology	Process Options
GROUNDWATER		
Containment	Physical or Gradient Control Barriers	◆ Vertical barriers (sheet piling, HDPE, or soil, bentonite, or concrete slurry walls) to restrict the inflow or outflow of groundwater. Gradient control maintains plume position.
In-Situ Approaches	Physical/Chemical Treatment	◆ Enhanced Bioremediation.
		◆ Air Sparging.
		◆ Chemical Oxidation (ISCO).
		◆ Permeable Reactive Barriers (PBRs).
	Institutional Controls	◆ Groundwater Use Restrictions.
Ex-Situ Treatment	Pumping and Treatment	◆ Groundwater is pumped annd either disposed of off-site or pre-treated and disposed or discharged.
	Excavation/trenching	◆ Excavation and removal of contamination or excavation of interceptor trenches used to gain access to groundwater.
Passive	Monitored Natural Attenuation	◆ Groundwater is monitored for COPCs and geochemical parameters to demonstrate degradation.
SOIL Above and Below the Groundwater Table		
Containment	Capping/ Engineered Barriers	◆ Soil, aggregate stone asphalt, concrete, or geosynthetic covers used for capping.
In-situ Approaches	Physical/Chemical Treatment	◆ Solidification/Stabilization (ISS).
		◆ Soil Vapor Extraction (SVE).
		◆ Chemical and Surfactant-Enhanced Oxidation (ISCO and SISCO).
		◆ Thermal Treatment.
	Institutional Controls	◆ Access and Use Restrictions.
Ex-situ Approaches	Excavation/Disposal	◆ Excavation for disposal at a landfill or relocation.
	Excavation/Treatment	◆ Excavation and low to medium temperature thermal desportion.

Table 2 - General Response Options
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action	Remedial Technology	Process Options
SEDIMENT		
In-situ Approaches	Implement institutional controls	◆ Waterway restrictions, such as dredging limitations, and no anchoring and no wake zones.
		◆ Signage, including sediment contact and fish consumption advisories.
		◆ Commercial fishing bans.
		◆ Maintenance agreements for dams or other structures.
	Monitored natural recovery - physical isolation or biological and chemical degradation	◆ MNR can be used in environments where contaminant concentrations may be expected to be reduced with time due to natural physical isolation, or chemical or biological transformation/sequestration.
	Enhanced Monitored Natural Recovery	◆ A thin layer of sand or other material is added to enhance natural processes, can be used in similar environments as MNR.
	Containment In-situ capping	◆ Single-layer granular cap, thickness and grain size dependant on energy in environment and required durability of cap.
		◆ Multi-layer granular cap, same variables as single-layer cap, outer layer often composed of armor-stone.
		◆ Combination granular and geotextile cap.
	In-situ treatment	◆ Addition of sequestration agent (e.g., black carbon).
		◆ Addition of degradation agent (e.g., nutrients to foster bacterial degradation).
Ex-situ Approaches	Dredging	◆ Mechanical dredging.
		◆ Hydraulic dredging.
		◆ Hybrid method dredging.
		◆ Backfill of dredged area, as needed.
	Excavation	◆ Dry excavation including water control by in-stream diversion or dewatering, and backfilling, as needed.
Discharge/Disposal of Dredge Spoils (Sediment and Water)	Sediment Treatment and Disposal	◆ Sediment is dewatered on site, then shipped off site for beneficial reuse or disposal in landfill, or other.
		◆ Sediment is dewatered and treated/stabilized on site, then shipped off site for beneficial reuse or disposal in landfill.
	Water Treatment and Disposal	◆ Water from dewatered sediment treated in on-site treatment system, sampled, and discharged to surface water.
		◆ Water from dewatered sediment treated in on-site treatment system, sampled, and discharged to POTW.

Table 2 - General Response Options
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action	Remedial Technology	Process Options
DNAPL		
Containment	Physical Barriers	◆ Physical barriers such as sheet piling, HDPE or soil, bentonite, or concrete slurry walls to restrict the migration of DNAPL through the soil.
	Capping/ Engineered Barriers	◆ Soil or aggregate stone cover or asphalt, concrete, or geosynthetic covers used for capping.
Ex-situ Approaches	Well Recovery	◆ Free Product Recovery.
		◆ Enhanced Recovery with Pressure Pulse Technology (PPT).
		◆ Enhanced Recovery with Electrical Resistance Heating (ERH).
VAPOR INTRUSION		
Active Mitigation	Active remediation or pressurization	◆ Soil and/or groundwater remediation.
		◆ Building Mitigation; sub-slab (or sub-membrane) pressurization or depressurization.
		◆ Building Mitigation; building pressurization.
		◆ Building Mitigation; Indoor air treatment.
Passive Mitigation	Passive Mitigation	◆ Sub-slab barriers (HDPE liners, spray-on asphaltic emulsions).
		◆ Passive venting; used in conjunction with sub-slab barriers.
		◆ Institutional Controls to control access and use.

Notes:

Major remedial approaches/alternatives for managing risks from contaminated sediment are described in *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* , USEPA OSWER (EPA-540-R-05-012), December 2005.
DNAPL - Tar and Tar Saturated soil below the groundwater table
HDPE - High Density Polyethelene
MNR - Monitored natural recovery
OSWER - Office of Solid Waste and Emergency Response
POTW - Publicly-owned treatment works
USEPA - United States Environmental Protection Agency

Table 3A - Description of Potential Remedial Technologies and Process Options - Groundwater
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
Containment				
Physical Barriers	• Subsurface barriers composed of either sheet piling, HDPE or soil, bentonite and concrete slurry walls. Walls are used to contain and divert contaminated groundwater away from sensitive (drinking) water or provide a barrier for the groundwater treatment system.	• May be combined with another process option to treat groundwater in order to be effective. • Effective at containing and isolating groundwater only.	• Wall composition may degrade, deteriorate, or be damaged by nearby activity. • Requires continued monitoring inside and outside the physical barriers for wall leakages.	Moderate
Gradient Control Pumping	• Gradient control in the form of a pumping system designed to capture the plume, thereby controlling and maintaining the size and the location of the plume.	• May be combined with another process option to treat groundwater in order to be effective. • Effective at containing and isolating groundwater only.	• Easy to implement if groundwater characteristics are understood • Operation and maintenance may become difficult and costly since the system should run indefinitely	Moderate
In-situ Approaches				
Enhanced Bioremediation	• Natural or introduced microbes are stimulated by circulating air or water-based oxygen, nitrate, methane and peroxide solutions through contaminated media to enhance in situ biological degradation of organic contaminants. Wastewater may be discharged, recharged to the aquifer and/or additionally treated. This method is often used in conjunction with Soil Vapor Extraction (SVE).	• Effective for PAHs and PVOCs. • Not effective technology if heavy contamination such as free product are still present. • May disrupt groundwater flow patterns and biological activities in the saturated and vadose soil zones.	• Air injection system may also include a recovery system such as a SVE. • Bio-fouling of the wells can occur (clustering of microbes near nutrients at injection wells) and will require maintenance and rotation of injection wells. • Pump and treat system may need to be installed to assist in the control of the groundwater. • Requires continued monitoring inside and outside the injection zones. • Limited ability of recovery for stratified soils with low permeability layers such as clay or fractured rock.	Moderate to High
Air Sparging	• The process uses horizontal and/or vertical wells to inject air directly into the groundwater and then a SVE is needed to extract PVOCs being volatilized by the presence of the injected air.	• Effective for contaminants that volatilize in the presence of air. • Not effective technology if heavy contamination such as free product are still present. • May disrupt groundwater flow patterns and biological activities in the saturated and vadose soil zones. • Not effective in addressing certain PAHs, which do not volatilize	• Air injection system may also include recovery such as a SVE system. • Horizontal wells may induce plume migration. • Requires monitoring inside and outside the injection zones. • Limited ability of recovery for stratified soils with low permeability layers such as clay or fractured rock.	Moderate to High

Table 3A - Description of Potential Remedial Technologies and Process Options - Groundwater
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
In-situ Approaches continued				
Chemical Oxidation (ISCO)	◆ Converts contaminants to non-hazardous or less toxic compounds by injecting chemicals via wells within the contaminate zone then extracted by pumping or other technologies. ◆ Most common chemicals used are permanganate, peroxide (Fenton's reagent), and ozone.	◆ Effective for PVOCs, and PAHs. ◆ Some limited effectiveness if free product is present. ◆ Rapid and extensive reactions with and destruction of various contaminants. ◆ Can be tailored to a site and implemented with relatively simple and readily available equipment.	◆ Extensive subsurface conditions must be known in order to assist with understanding potential ISCO reactions. ◆ Requires handling, storage, distribution, and safety precautions for the large quantities of hazardous oxidizing chemicals. ◆ The soil pH must be adjusted to levels between 3 and 5 for Fenton's reagent, buffering agents such as carbonates may prevent the reduction of pH to the required zone.	Moderate to High
Permeable Reactive Barriers (PRBs)	◆ A passive technology using a permeable barrier downgradient from the plume. A media, often iron or peat, is located in the barrier and reacts with the plume making it either precipitate or stabilize.	◆ Effective at hydraulic flow control. ◆ Passive technology requires less operational costs ◆ Effective at recovering free product ◆ Long-term effectiveness is not easy to predict ◆ Low short-term exposure risk (odors and construction worker and community exposures) ◆ Requires maintenance/replacement of PRB media. ◆ System efficiency decreases as the PRB media increases with precipitation of compounds or from biological activities.	◆ Difficult to implement in highly variable groundwater flow or where cross groundwater currents, seasonal or long term groundwater flow direction can change. ◆ Requires adequate space to install sheet pile or slurry walls ◆ Requires monitoring to ensure the continued groundwater flow through the PRB. ◆ Requires materials handling of spent PRB media.	Moderate to High

Table 3A - Description of Potential Remedial Technologies and Process Options - Groundwater
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
Ex-situ Approaches				
Groundwater Pumping and Treatment or off-site Disposal	• Use liquid ring or submersible pumps to extract groundwater. Then groundwater is sent for disposal or treated and discharged, disposed or reinjected. Treatment depends on ultimate destination of effluent. Pumping is also used for hydraulic control limiting flow and contaminant migration.	• Addresses a wide range of contaminants. • Moderately effective technology in the recovery of free product. • This technology is often used in conjunction with other technologies to improve recovery. • Residual saturation of the contaminant in the soil pores cannot be removed by groundwater pumping. Contaminants tend to be sorbed in the soil matrix. • Effectiveness and timeframe of pump and treat recovery is difficult to accurately forecast.	• Groundwater pumping is not applicable for contaminants with high residual saturation, contaminants with high sorption capabilities, and homogeneous aquifers with hydraulic conductivity less than 10-5 cm/sec. • Requires maintenance/ replacement of treatment media; activated carbon or other media.	Moderate to High
Excavation/ Trenching	• contaminated soil, tar-saturated soil and surrounding soil are excavated. The excavated pits or trenches may then be pumped out and treated or disposed. Virgin soil or stone is often used to backfill the excavation pits or trenches and then compacted.	• Addresses a wide range of contaminants but only the area and volume excavated - residual impacts are anticipated. • Requires engineering, erosion and access controls during construction for managing fugitive emissions, soil, and public access. • Moderate potential short term exposure risk (odors, and construction worker and community exposures). • Technology does not treat the groundwater but enables the removal of impacted source material and/or impacted soil along with access to groundwater. • May be used in conjunction with pump and treat or pump and disposal. • Subsurface structures or above ground structures may make this technology less effective.	• Limited to availability of space for staging and handling of soil material and water treatment system, if needed • Air quality controls required to address VOC emissions and dust. • Groundwater pumping occurs in the open trenches instead of wells. • Requires maintenance/ replacement of treatment media; activated carbon or other media. • Soil stability devices may be utilized to support surface structures.	Moderate to High

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
Passive Approach				
Monitored Natural Attenuation	• Verify that loss of contaminants is naturally occurring and that contaminant degradation and natural processes will reduce contaminant concentrations to acceptable levels. Demonstrate attenuation through a groundwater sampling network, contaminant trend analysis, mass balance calculations and modeling.	• Relies on biodegradation, sorption to soil, and low bioavailability to microorganisms. • Effectiveness and timeframe of attenuation is unknown. • Dependent on physical and biological characteristics of system. • Does not damage existing habitat or biological community .	• Easy implementation • Requires monitoring with relatively well-established methods • No construction or infrastructure required • Little disruption to local residents • Can be combined with other options	Low to Moderate
Institutional Controls - Access and Use Restrictions				
Institutional Controls - Access and Use Restrictions	• City Ordinances or Zoning Restrictions: Through community and city ordinance, prohibit use of groundwater wells and the installation of potable water wells.	• Minimal potential short term exposure risk. • Administratively effective and reliable; relies on local government action to establish, enforce and restrict.	• Easy implementation • Administratively implementable	Low

Notes:
HDPE - high density polyethylene
SVE - soil vapor extraction
MNA - monitored natural attenuation
PVOCs - petroleum volatile organic compounds
PAHs - polynuclear aromatic hydrocarbons
PRB - permeable reactive barrier

Table 3B - Description of Potential Remedial Technologies and Process Options - Soil
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
Containment				
Capping/ Containment	◆ Soil, aggregate, asphalt, concrete, or multi-layer geosynthetic caps used for creating a physical barrier separation between the affected soil and the surface. Multi-layer caps provide redundancy and asphalt, concrete and multi-layer caps are impervious	◆ Technology alone does not treat the soil but enables the isolation of contaminated soil. ◆ Also effective in preventing continued migration of contaminants from soil to groundwater due to precipitation if cap is impervious.	◆ Capping material composition may degrade, deteriorate, or be damaged intentionally or over time. ◆ Requires monitoring in the capped areas for cap leakages. ◆ Technology has been extensively and is relatively easy to implement unless openings are required for utilities, etc.	Low to Moderate
In-situ Approaches				
Institutional Controls - Access and Use Restrictions	◆ Zoning restrictions, deed covenants, fencing, and signage: Through community and city zoning, property deed covenants and restriction, fencing property from entry, and awareness signage to control access and potential contact with soil+B10	◆ Minimal potential short term exposure risk ◆ Administratively effective and reliable; relies on local government and legal property contracts to establish, enforce and restrict.	◆ Easy implementation ◆ Administratively implementable	Low
In-situ Stabilization/ Solidification (ISS)	◆ Mobility and/or toxicity of contaminants is reduced by physical bonding/chemical reactions. Most common technique for solidification is the utilization of cement to produce a monolithic mass resistant to leaching. ◆ Methods for delivery include auger, infection, or mechanical mix ◆ Has been used at coal tar/MGP sites	◆ Effective for weathered coal tar, PAHs, PVOCs, and metals. ◆ Limited effectiveness where high percentage of free product present or highly heterogeneous ◆ Monolith may deteriorate over time ◆ May provide limited, short-term risk reduction, and potentially acceptable long-term risk reduction ◆ Contaminants may become immobilized by stabilization/ solidification methods but risk "weathering" or deterioration of products that may release contaminates in the future.	◆ Implementation affected by obstructions, may require pre-excavation of material/debris. ◆ Requires monitoring to ensure performance. ◆ Most reagents and additives are widely available. ◆ Less disruptive to local residents than excavation. ◆ Can be combined with other technologies. ◆ Requires specifying optimal mix methods to achieve desired performance criteria. ◆ Limited availability of qualified contractors	Moderate
Soil Vapor Extraction (SVE)	◆ A vacuum is applied to extraction wells to remove gas-phase contaminants from the vadose (unsaturated) zone. Groundwater pumps sometimes used to keep the water table level from raising due to the vacuum extraction process.	◆ Effective at PVOCs. ◆ Effective for facilitating extraction of deep contamination. ◆ Requires maintenance/replacement of air filter media/ treatment system. ◆ High moisture in the soils require higher vacuums and can hinder operation of system. ◆ Not effective in the recovery of free product.	◆ Removal rates may be reduced by high organic content, extremely dry soil or high sorption capacity of PVOCs in soil. ◆ May require off-gas treatment system ◆ May also require a pump and treat system for the groundwater to keep the water table from entering the vadose zone. ◆ Technology has been extensively used in the past which allows for a wide range of system choices and capabilities.	Moderate

Table 3B - Description of Potential Remedial Technologies and Process Options - Soil
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
In-situ Approaches continued				
Chemical and Surfactant-Enhanced Oxidation (ISCO and SISCO)	◆ ISCO converts contaminants to inert or less toxic compounds by injecting chemicals via wells within the contaminate zone then extracted by pumping or other technologies. ◆ Most common chemicals used are permanganate, peroxide (Fenton's reagent), and ozone. Surfactants are sometimes added to enhance the effectiveness	◆ Effective for PVOCs, SVOCs, and PAHs. ◆ Some limited effectiveness in the recovery of heavy contamination such as tar saturated soil, improved with the addition of a surfactant. ◆ Rapid and extensive reactions with and destruction of various contaminants. ◆ Effective for many organics and subsurface environments. ◆ Can be tailored to a site and implemented with relatively simple and readily available equipment.	◆ Extensive subsurface conditions must be known in order to assist with understanding potential ISCO and SISCO reactions. ◆ Requires handling, storage, distribution, and safety precautions for the large quantities of hazardous oxidizing chemicals. ◆ The soil pH must be adjusted to levels between 3 and 5 for Fenton's reagent, buffering agents such as carbonates may prevent the reduction of pH to the required zone.	Moderate to High
Thermal Treatment	◆ Raising the soil temperatures increases the volatilization rates and reduces viscosity of many DNAPLs including coal tar. Thermal treatment uses a heating or energy inducing method along with an extraction method, either vapor and/or liquid recovery (SVE). ◆ Steam/hot water is forced through injection wells within an aquifer (or thermochemical heating (THC) is used to apply heat) to enhance vaporization of PVOCs and PAHs. As vaporized compounds rise vapor is removed by vacuum extraction then treated. Water may be treated and reused. THC can also be used for in-situ thermochemical solidification (ISTS) where a non-leachable solid is formed.	◆ Effective for tar saturated soil, PVOCs, and PAHs. ◆ Can be used to remove large portions of oily waste accumulations and to retard downward and lateral migration of organic contaminants. ◆ Treatment has been used to mobilize oils, coal tars, and other DNAPL. ◆ Hot water or steam can be injected at the perimeter of a plume and extracted from the center of the plume. ◆ Requires substantial and sustained heating and drying of the soil to be effective. ◆ Soil type, contaminant characteristics and concentrations, geology, and hydrogeology can significantly impact process effectiveness.	◆ Extensive subsurface conditions must be known. ◆ This technique uses a large amount of water or other energy and can adversely affect the water table. Monitoring beyond the perimeter must occur to ensure the contaminants are not mobilizing out of the treatment zone or leaching. ◆ Dissolved iron from coal tar heating may separate and cause an increase in dissolved iron in the groundwater; technology considerations should be considered for the recovery of the released iron in the groundwater. ◆ Buried metal probes and high temperatures with TCH require extra safety precautions.	Moderate to High

Table 3B - Description of Potential Remedial Technologies and Process Options - Soil
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
Ex-situ Approaches				
Excavation and Disposal	◆ Impacted soil and surrounding soil are excavated. The soil is staged, pretreatment applied, or directly loading into trucks and disposed. Virgin soil or stone is often used to backfill the excavation pits or trenches and then compacted. ◆ The excavated soil can also be treated on-site and disposed in a specially constructed on-site landfill disposal facility.	◆ Effective for a wide range of contaminants. ◆ Requires engineering, erosion and access controls during construction for managing fugitive emissions, soil, and public access ◆ Moderate potential short term exposure risk (odors, and construction worker and community exposures) ◆ Technology alone does not treat the soil or groundwater but enables the removal of impacted source material and/or impacted soil. ◆ Highly effective and predictable timetable. ◆ Subsurface structures or above ground structures may make this technology less effective.	◆ Limited to availability of space for staging and handling of soil material and water treatment system, if needed ◆ Air quality controls need to be addressed for emissions and dust. ◆ Soil stability devices maybe utilized to support surface structures.	Moderate to High
Excavation and On or Off-Site Treatment Using Thermal Desorption	◆ Impacted soil and surrounding soil are excavated and then thermally treated. Thermal processes use heat to increase the volatility; burn, decompose, or melt the contaminants. Separation technologies include thermal desorption and hot gas decontamination. Destruction technologies include incineration. ◆ If the treatment is conducted on-site, the ash may be suitable for use as excavation backfill, or may be placed in an on-site monofill. If the material is shipped off-site for treatment, it will typically be disposed of in a landfill that may require pretreatment prior to disposal.	◆ Effective for a wide range of contaminants. ◆ Requires engineering, erosion and access controls during construction for managing fugitive emissions, soil, and public access. ◆ Moderate potential short term exposure risk (odors, and construction worker and community exposures). ◆ Technology destroys the contaminants. ◆ Highly effective and predictable timetable. ◆ Subsurface structures or above ground structures cause additional screening, segregation and could increase the number of treatment cycles.	◆ Limited to availability of space for staging and handling of soil material and water treatment system, if needed. ◆ Air quality controls need to be addressed for emissions and dust. Significant effort to mobilize and permit the treatment unit. ◆ Large energy sources needed to operate the treatment unit. Unit cost decreases as the volume to be treated increases. ◆ Soil stability devices maybe utilized to support surface structures.	Moderate to High
Institutional Controls - Access and Use Restrictions				
Institutional Controls - Access and Use Restrictions	◆ Deed Restrictions or Zoning Restrictions: Through deed restrictions, prohibit or restrict use of the site so that development or excavation are not allowed.	◆ Minimal potential short term exposure risk. ◆ Administratively effective and reliable; relies on local government action to establish, enforce and restrict.	◆ Easy implementation. ◆ Administratively implementable.	Low

Notes:
ISS - in-situ solidification/stabilization
PVOCs - petroleum volatile organic compounds
SVE - soil vapor extraction
PAHs - polynuclear aromatic hydrocarbons
ISCO - in-situ chemical oxidation
SISCO - surfactant-enhanced n-situ chemical oxidation
THC - thermochemcial heating
ISTS - in-situ thermochemical solidification

Table 3C - Description of Potential Remedial Technologies and Process Options - Sediment
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action and Remedial Technology	Description of Process Option	Effectiveness	Implementability	Relative Cost
No Action - None	• No action taken to reduce or monitor site risks.	• No added risk during short term • Not proven or reliable	• Easy implementation • Potential for negative public perception	Low
In-situ Approaches				
Institutional Controls - Access and Use Restrictions	• Waterway Use Restrictions: Through community ordinance, require a permit for dredging of sediment and prohibit use of boat anchors within the institutional control zone. This could include restrictions on navigational dredging.	• Minimal potential short term exposure risk • Administratively effective and reliable; relies on local government action to establish, enforce and restrict	• Easy implementation • Administratively implementable	Low
	• Fish Consumption Advisories and Fishing Bans: Informing the public that they should not consume fish from an area, or consume no more than a specified number of fish meals over a specific period of time from a particular area.	• Not enforceable controls • Variable	• Easy implementation • Potential for negative public perception	Low
	• Signs: Signs that are installed to prevent access and/or warn of the presence of site-related contaminants in sediment.	• Could be configured to address entire impacted area • Minimal potential short term exposure risk (odors and construction worker and community exposures) • Effective and reliable in reducing direct exposure risk; ineffective for addressing COPCs leaching to surface water or isolating contaminants from ecological receptors	• Easy implementation • Potential for negative public perception	Low
MNR - Physical Isolation	• Perform analyses to monitor sediment bathymetry over time and assess continued deposition and physical stability of sediment that can isolate contaminants from surface.	• Relies on natural deposition of clean sediment to bury or dilute contaminated sediment • Dependent on physical characteristics of system • Highly effective when source is controlled and sediment bed is stable • Does not damage existing habitat or biological community • May provide low-level, short-term risk reduction, but potentially acceptable long-term risk reduction	• Easy implementation • Requires monitoring with relatively well-established methods • No construction or infrastructure required • Little disruption to local residents • Can be combined with other options	Low to Moderate

Table 3C - Description of Potential Remedial Technologies and Process Options - Sediment
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action and Remedial Technology	Description of Process Option	Effectiveness	Implementability	Relative Cost
In-situ Approaches continued				
MNR - Biological and Chemical Degradation	◆ Verify that loss of contaminants is naturally occurring and that contaminant degradation and natural processes will reduce contaminant concentrations to acceptable levels. Demonstrate recovery through a sediment sampling network, contaminant trend analysis, mass balance calculations and modeling.	◆ Relies on biodegradation, sorption to sediment, and low bioavailbility to microorganisms ◆ Effectiveness and timeframe of natural recovery is unknown ◆ Dependent on physical and biological characteristics of system ◆ Highly effective when source is controlled and sediment bed is stable ◆ Does not damage existing habitat or biological community ◆ May provide low-level, short-term risk reduction, but potentially acceptable long-term risk reduction	◆ Easy implementation ◆ Requires monitoring with relatively well-established methods ◆ No construction or infrastructure required ◆ Little disruption to local residents ◆ Can be combined with other options	Low to Moderate
Enhanced MNR	◆ Accelerate the natural recovery process through engineering, with the addition of a thin layer of sediment such as granular material. Verify reduction in contaminant concentrations through monitoring.	◆ Short term disruption of benthic community ◆ Reduces surface sediment concentration and risk ◆ Provides new substrate for benthic invertebrates ◆ May provide low-level, short-term risk reduction, but potentially acceptable long-term risk reduction	◆ Moderately easy to implement ◆ Requires monitoring with relatively well-established methods ◆ May be difficult to place in steep slope, high flow regimes, and unstable sediment environments ◆ May be difficult to implement around in-water infrastructure (e.g., piers, pilings, buried utilities) ◆ Requires less material-handling infrastructure than dredging	Low to Moderate

Table 3C - Description of Potential Remedial Technologies and Process Options - Sediment
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action and Remedial Technology	Description of Process Option	Effectiveness	Implementability	Relative Cost
In-situ Approaches continued				
Containment - In-situ Sediment Capping	◆ Earthen or geosynthetic materials placed on top of sediment to contain and isolate contaminants and reduce exposure risks. ◆ Cap may be single or multiple layers of granular material with a range of grain sizes and may combine earthen and geosynthetic materials. ◆ Does not require removal of affected sediment.	◆ Effective at rapidly reducing risk to human health and isolating contaminants from ecological receptors ◆ Effective at controlling sediment from suspending in water column ◆ Potential for scouring or a catastrophic event that could damage the cap ◆ Disrupts benthic community ◆ Low short-term exposure risk (odors and construction worker and community exposures) ◆ Provides new substrate for benthic invertebrates ◆ Cap requires maintenance and monitoring with relatively well-established methods ◆ Requires institutional controls to aid in maintenance of cap ◆ May provide moderate- to high-level, long term risk reduction depending on cap design, placement, construction, and maintenance	◆ May be difficult to place in shallow water, steep slope and unstable sediment ◆ Difficult to implement in high river flow regimes ◆ Limited to availability of space for staging and handling of cap materials ◆ May be significant disruption to waterway users ◆ May be difficult to implement around in-water infrastructure (e.g., piers, pilings, buried utilities) ◆ Requires adequate water depth to accommodate cap with existing uses (e.g., navigation, flood control) ◆ Requires less material-handling infrastructure than dredging ◆ Is an acceptable strategy and proven for managing contaminated sediments ◆ Requires permitting	Moderate
In-Situ Treatment	◆ Incorporating amendments/reagents into sediment to sequester contaminants and reduce bioavailability ◆ Several methods for delivery including injection and raking. ◆ Does not require removal of affected sediment. ◆Emerging technology	◆ Effective at rapidly reducing risk to ecological receptors ◆ Effective at reducing bioavailability in pilot scale evaluations ◆ Potential for scouring or a catastrophic event that could remove amendments/reagents ◆ Amendments/reagents may adversely interact with water column ◆ Low short-term exposure risk (odors and construction worker and community exposures) ◆ Provides new substrate for benthic invertebrates ◆ Requires monitoring to evaluate effectiveness - long term performance is uncertain ◆ Institutional controls to minimize disturbance increases effectiveness	◆ May be difficult to place and ensure mixing of amendment/reagent ◆ Difficult to implement in high river flow regimes and maintain placement ◆ Limited to availability of space for staging and handling of amendment/reagent materials ◆ May be difficult to implement around in-water infrastructure (e.g., piers, pilings, buried utilities) ◆ Process challenges related to strong adsorption and low permeability materials ◆ Requires less material-handling infrastructure than dredging and capping	Low to Moderate

Table 3C - Description of Potential Remedial Technologies and Process Options - Sediment
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action and Remedial Technology	Description of Process Option	Effectiveness	Implementability	Relative Cost
Ex-situ Approaches				
Dredging/ Excavation	• River sediments are removed from the river bottom by means of mechanical and/or hydraulic dredging equipment. Dredged sediments are then treated and/or disposed at an on- or off-site facility.	• Long-term effectiveness for controlling sediment from suspending in water column • Requires engineering, erosion and access controls during construction for managing fugitive emissions, sediment, and public access • Moderate potential short term exposure risk (odors, and construction worker and community exposures) • Disrupts benthic community • Contaminated sediments may resuspend and be transported downstream • May provide moderate- to high-level, long-term risk reduction depending on effectiveness of dredging and combined use of cap or sand cover to manage residuals	• Limited to availability of space for staging and handling of dredge material and water treatment system, if needed • Extensive amounts of debris or presence of bedrock or weather bedrock makes implementation difficult • Typical methods include mechanical or hydraulic • May be implemented via conventional excavation method (in the "dry") in shallow waters or if water can be readily diverted • Requires permitting • Requires coordination with waterway users due to magnitude and duration of work • May be significant disruption to waterway users • Requires identification and use of appropriate disposal facility, including transportation • River flow velocities may make it difficult to control turbidity • Difficult to remove all contaminated sediment/some residuals may remain • Can be combined with capping for additional risk reduction	Moderate to High
Disposal of Dredge/Excavation Spoils				
Discharge/ Disposal - On-site	• Water from dewatered sediment treated in on-site water treatment system and discharged to surface water or POTW	• Combined with another process option to treat generated wastewater effectively • Limited by on-site surface water body discharge requirements	• Permit required • Pilot testing or modeling may be required	Low to Moderate
Discharge/ Disposal - Off-site	• <u>Landfilling:</u> Treated or untreated sediments are disposed of at an off-site licensed landfill.	• Combined with dredging; potentially limited by the volume of contaminated sediment removed • Effective at reducing direct exposure risk and leaching of COPCs from sediment to surface water • Moderate potential short term exposure risk (vapor, odors, and construction worker and community exposures)	• Transportation of the soil through populated areas may affect community acceptance due to noise, potential accidents, and use of carbon-based fuels. • Limited by disposal facility availability	Moderate to High

Notes:
COPC - Constituent of potential concern
MNR - Monitored natural recovery
POTW - Publicly-owned treatment works

Table 3D - Description of Potential Remedial Technologies and Process Options - DNAPL
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
Containment				
Physical Barriers	◆ Subsurface barriers composed of either sheet piling, HDPE or soil, bentonite and concrete slurry walls keyed into a confining layer. Walls are used to contain and divert DNAPL from drinking water and provide a barrier for a groundwater treatment system. In addition the subsurface barriers contain contaminants and impacted soil.	◆ May be combined with another process option to treat groundwater. ◆ Effective at containing and isolating DNAPL.	◆ Capping material composition may degrade, deteriorate, or be damaged intentionally or over time. ◆ Requires monitoring in the capped areas for cap leakages. ◆ Technology has been extensively and is relatively easy to implement unless openings are required for utilities, etc.	Moderate
Capping/ Engineered Barriers	◆ Soil, asphalt, concrete, or geosynthetic covers used for creating a physical barrier separation between the DNAPL and the surface or used as a subsurface 'bowl, holding the DNAPL and preventing vertical migration.	◆ Technology alone does not treat DNAPL but enables the isolation of the DNAPL. ◆ Effective at isolating the DNAPL so that it does not spread.	◆ Capping material composition may degrade, deteriorate, or be damaged intentionally or over time. ◆ Requires monitoring in the capped areas for cap leakages. ◆ Technology has been extensively and is relatively easy to implement unless openings are required for utilities, etc.	Low to Moderate
Ex-situ Approaches				
Free Product Recovery	◆ Undissolved liquid phase organics are removed from substrate by active (pumping) or passive collection systems in wells, sumps or trenches. Recovered DNAPL generally disposed off site.	◆ Effective for removal of free product, including DNAPL . ◆ Can effectively reduce the quantity of product which may be difficult to remove through other remedial technologies, but may take a very long time. ◆ DNAPL tends to adhere to soil particles. Free product removal or pumping often leaves behind residual contaminants, which require further remedial technologies.	◆ Requires trenching, excavation pits, or extraction wells to access free product. ◆ Technology has been extensively used in the past which allows for a wide range of system choices and capabilities.	Low to Moderate
Enhanced Recovery with Pressure Pulse Technology (PPT)	◆ Hydraulic pulse creates high pressure intervals at or near the water table to increase mobility and flow of DNAPL. ◆ The PPT system often includes a SVE and/or a well extraction system.	◆ Effective for NAPL and DNAPL. ◆ Technology has effectively been used in the petroleum industry to increase movement of oil for greater recovery. ◆ PPT has been used to enhance other remediation technologies such as pump and treat, bioremediation, PRBs, and electrical heating. ◆ Main efficiency difference of petroleum industry use is the deep hydrogeologic formations which differ greatly from the much shallower depth for remediation applications.	◆ Extensive subsurface conditions must be known. ◆ Technology has been extensively used in the past which allows for a wide range of system choices and capabilities. Most applications have been in the petroleum industry and not remediation. ◆ Additional recovery systems such as SVE or pump and treat may be used to enhance recovery.	Moderate to High
Enhanced Recovery with Electrical Resistance Heating (ERH)	◆ Electrical current is passed through a targeted contaminant volume between subsurface electrode elements. The heat decreases the viscosity of the DNAPL, allowing greater recovery. ◆ A SVE system is used to extract the contaminants, typically from the central neutral electrode location.	◆ Effective for DNAPL as well as soil. ◆ Effective at increasing the temperature below grade to enhance movement.	◆ Operational costs are relatively high. ◆ The subsurface conditions should be well known and mapped. ◆ Buried metal probes and high voltages require extra safety precautions and barriers to prevent exposure. ◆ Technology has been extensively used in the past which allows for a range of system choices and capabilities.	Moderate to High

Table 3D - Description of Potential Remedial Technologies and Process Options - DNAPL
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action/Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost
Institutional Controls - Access and Use Restrictions				
Institutional Controls - Access and Use Restrictions	◆ Deed Restrictions or City ordinance: Through deed restrictions, prohibit or restrict use of the site so that development or excavation are not allowed. Ordinance prevents installation of potable water supply well.	◆ Minimal potential short term exposure risk. ◆ Administratively effective and reliable; relies on local government action to establish, enforce and restrict.	◆ Easy implementation. ◆ Administratively implementable.	Low

Notes:
DNAPL - dense non-aqueous phase liquid
PPT - pressure pulse technology
ERH - electric resistance heating
SVE - soil vapor extraction
HDPE - high density polyethylene
PRB - permeable reactive barriers

Table 3E - Description of Potential Remedial Technologies and Process Options - Soil Vapor
Multi-Site Feasibility Study Support Document
Integrys Business Support, LLC

General Response Action and Remedial Technology	Description of Process Option	Effectiveness	Implementability	Relative Cost
Active Mitigation Approaches				
Soil and/or groundwater remediation	◆ A vast array of remedial technologies to remove the source of contamination or plume located under a building. The primary objective would be to remove the potential cause and continuance of soil gas that could enter into an above ground structure.	◆ Effectiveness depends on the technology used and the success at removing the potential contaminants from releasing soil gases. ◆ Long term effectiveness could be greatly reduced if contaminant source material is not removed.	◆ A wide selection of technologies have been extensively used in the past which allows for a wide range of system choices and capabilities. ◆ Potential for large and long building access disruptions. ◆ Subsurface structures under the building may present challenges to implement remedial technologies.	High
Sub-slab (or sub-membrane) pressurization or depressurization)	◆ Electric powered fans that draw air from outside are directed to under the buildings' slab or membrane to create a positive pressure under the building. This positive pressure displaces potential soil gas from raising up into the building by creating a pressure barrier. ◆ The most common soil vapor action mitigation approach is sub-slab (or sub-membrane) depressurization. Utilizing a electric powered motor fan to draw in air and soil gas beneath the slab or membrane (typically HDPE) and exhaust the gases above and outside the building. Air and soil vapors migrate to the negative draw from the exhaust system.	◆ Effective mitigation technology for benzene, naphthalene and other soil gases. ◆ System effectiveness can be reduced if slab or membrane integrity is compromised. ◆ Saturated and low-permeable soils reduce gas movement often requiring more exhaust/blower units to the system. ◆ Pressurization often requires a larger system and energy costs compared to depressurization. ◆ Filters, if applicable, to the exhaust/blower will require maintenance and replacement as needed to maintain efficient operation.	◆ Easy implementation for retro-fitting existing buildings. ◆ Requires monitoring and maintenance to ensure continued motorized fan operation. ◆ Subsurface conditions and soil properties should be known to design a system that creates proper pressurization or depressurization. ◆ Slab and/or membrane need to be sealed very well. ◆ System needs to be periodically inspected to insure leaks in the slab or membrane are not present. ◆ Technologies have been extensively used in the past which allows for a wide range of system choices and capabilities.	Low to Moderate

Table 3E - Description of Potential Remedial Technologies and Process Options - Soil Vapor
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General Response Action and Remedial Technology	Description of Process Option	Effectiveness	Implementability	Relative Cost
Active Mitigation Approaches continued				
Building Pressurization	◆ The buildings HVAC system is optimized to create a positive building pressure relative to the sub-slab pressure. The building positive pressure displaces potential soil gas from raising up into the building by creating a pressure barrier.	◆ Effective mitigation technology for benzene, naphthalene and other soil gases. ◆ System effectiveness can be obtained by a relatively small increase in the building pressure. ◆ Saturated and low-permeable soils reduce gas movement often requiring more exhaust/blower units to the system. ◆ Proper air balancing will need to be preformed to insure even positive pressure at least throughout the lowest level of the building. ◆ Periodic maintenance and pressure tests will need to be conducted to sustain proper positive pressure. ◆ HVAC systems are often turned off or reduce operations during weekends and off-peak usage times. This can cause pressure equalization in the building reducing or eliminating the effectiveness of positive building pressure mitigation approach. System designs will need to account for pressurization during these off-peak times.	◆ Easy implementation for retro-fitting existing buildings. ◆ Requires monitoring and maintenance to ensure continued HVAC positive pressure in the building. ◆ HVAC system capabilities should be known to design/retro-fit a system that creates proper building pressurization. ◆ Slab and/or membrane should be sealed to increase the efficiency of the system. ◆ Technologies have been extensively used in the past which allows for a wide range of system choices and capabilities.	Moderate
Building Mitigation; Indoor air treatment	◆ An indoor air treatment system is installed to capture soil vapors that enter the building. This technology does not attempt to prevent soil gas from entering the building as with other technologies. ◆ Indoor air treatment systems are often used in conjunction with other mitigation technologies.	◆ Moderate effective mitigation technology for benzene, naphthalene and other soil gases. ◆ System effectiveness is dependant on the air treatment system size capabilities and the quantity and concentration of the soil vapor to be captured. ◆ Efficiency may decrease as air treatment media begins to fill. ◆ Proper system sizing is required to ensure that complete coverage is captured. ◆ Often and periodic maintenance and system tests will need to be conducted to sustain proper air treatment.	◆ Easy implementation for retro-fitting existing buildings. ◆ Requires monitoring and maintenance to ensure continued indoor air treatment. ◆ Waste generated (typically spent activated carbon) by treatment process will add to costs and implementation design considerations. ◆ Technologies have been moderately used in the past which allows for a range of system choices and capabilities.	Moderate to High

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General Response Action and Remedial Technology	Description of Process Option	Effectiveness	Implementability	Relative Cost
Passive Mitigation Approaches				
Sub-Slab Barriers	◆ Sub-slab barriers such as HDPE liners or spray-on asphalt sealants are used create an impenetrable layer that soil gases can not pass through. These barriers are easily installed at new construction buildings but often difficult and costly for existing buildings. ◆ Often sub-slab barriers are used in conjunction with passive venting or active mitigation approaches such as sub-slab depressurization.	◆ Moderate effective mitigation technology for benzene, naphthalene and other soil gases. ◆ System effectiveness is dependant on the initial and long-term air tight seal of the barrier. ◆ Efficiency decreases as deterioration, punctures, or incomplete seals in the barrier system allows for soil gas to enter into the building. ◆ If the barriers seal is compromised and retro-sitting efforts fail then active mitigation approaches will need to be investigated. ◆ Pressure tests can be conducted to verify system effectiveness.	◆ Easy implementation for new construction but often very difficult for retro-fitting existing buildings. ◆ Requires monitoring to ensure continued sub-slab barrier integrity. ◆ Extreme care must be taken when the system is installed and building construction continues to maintain the integrity and seal of the system. ◆ Often sub-slab barriers are installed in conjunction with other technologies and should be designed to allow for these other systems. ◆ Technology has been extensively used in the past which allows for a wide range of system choices and capabilities.	Low
Passive Venting	◆ Passive venting utilizes a sub-slab barrier (to keep soil gasses from migrating into the building), system of venting layers (often sand, gravel, or other high permeable aggregate with very low abrasive characteristics so as to not damage any sub-slab barriers) and a venting area where a vent pipe goes from the sub-slab area to an outside location. The passive system works to allow for lateral migration of soil gases to venting areas by natural pressure gradients and exhausting of gas vapors without mechanical processes. ◆ Almost exclusively utilized in conjunction with a sub-slab barrier system.	◆ Moderate effective mitigation technology for benzene, naphthalene and other soil gases. ◆ System effectiveness is dependant on the initial and long-term air tight seal of the sub-slab barrier and the natural conditions of the soil, venting layers, and outdoor conditions. ◆ Efficiency decreases as deterioration, punctures, or incomplete seals in the sub-slab barrier system allows for soil gas to enter into the building instead of flowing to the passive venting system. ◆ Efficiency decreases when outside conditions such as cold temperatures and low winds reduce suction and naturally drafting methods for the passive venting system. ◆ System effectiveness comparable to active systems can be achieved by increasing the number of venting areas, larger and more permeable venting layers, and insulating vent pipes. ◆ Pressure tests can be conducted to verify system effectiveness.	◆ Easy implementation for new construction but often very difficult for retro-fitting existing buildings. ◆ Requires monitoring to ensure continued sub-slab barrier integrity and proper venting. ◆ Passive venting system can often be designed to allow for future retro-fitting to an active venting system. ◆ Sub-slab soil conditions should be well known and an adequate venting layer of permeable material should provide for easy natural migration of soil gas. ◆ Technology has been extensively used in the past which allows for a wide range of system choices and capabilities.	Low to Moderate
Institutional Controls - Access and Use Restrictions				
Institutional Controls - Access and Use Restrictions	◆ Deed Restrictions or Zoning Restrictions: Through deed restrictions, prohibit or restrict occupancy in building or specify conditions of occupancy.	◆ Minimal potential short term exposure risk. ◆ Administratively effective and reliable; relies on local government action to establish, enforce and restrict.	◆ Easy implementation. ◆ Administratively implementable.	Low

Notes:
HDPE - high density polyethylene